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A MULTIMODAL APPROACH TO CHILDREN'S DECEPTIVE BEHAVIOR

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General Introduction

Introduction

During the last four years, several situations in which I had, for instance, noticed that suddenly all the cookies are gone from the jar, or that the walls of the living room became a painting canvas, led me to asking one of my children that specific question, that I know other parents also sometimes have to confront their offspring with: *"Are you lying to me?".* Clara, who is now almost five years old, then typically looks at me with a poker face, and somehow manages to muster a serious response: *"No, mom! Of course not! I swear. I'm telling the truth!".* However, after a while she recognizes that the situation is hopeless, gives in and admits the lie. My son Xavier, who just turned three, when confronted with the same question, reacts quite differently. His eyes then get a "special" shine, his mouth turns into a naughty smile that he barely tries to hide, and then he usually proceeds the conversation as follows:

[Xavier] "*No, Mom! I think it was Clara."*

[Me] *"Really Xavier? I see a Pinocchio nose growing!"*

[Xavier] *"Mom, no I'm not lying (while touching the nose!). Yes, I am!"*

The two situations sketched above illustrate differences in my children's lying behavior that intuitively seem related to the fact that they differ in age. Clara already has what we would call a more developed cognitive, emotional and social skills set, displays a stronger awareness of how other people (like her parents) look at her, and, accordingly, about the way she should behave. She is already able to interpret the nature of interpersonal interactions and communication. Xavier, on the other hand, still behaves like a boy of his age should. Being a child of three years old, he is literally an open book about his inner world, compared to how an adult would act, and he is still in the process of having to understand and accept that there are social rules and norms that need to be respected. At the same time, he does not yet fully grasp the notion that other people, with whom he interacts, may have a different perspective on things than he does, with different thoughts and emotions; he probably believes that his mom can actually look inside his head! This phenomenon of one being able to understand that another person may have a different perspective on things is called Theory of Mind (ToM), and is one of the most important landmarks in children's development. Put differently: ToM is the ability to attribute different mental states – beliefs, thoughts, points of view, feelings, etc., - to oneself and to the others. One of the most important reasons for the scientific interest in the deceptive behavior of children is that their lying behavior has been considered to shed light on universal properties in the development of ToM (Talwar, Gordon, & Lee, 2007; Talwar & Lee, 2008). This thesis is concerned with research on children's deceptive behavior[1]; particularly we aim to identify verbal and nonverbal cues of deception, explore the effect of different types of social partners and of context, and investigate the extent to which deception can be detected by human judges based on children's nonverbal behavior. In the remainder of this introduction, we will first present some insights into the development of lying behavior in general, then zoom in on what we know more specifically about deception in children, then describe previously tested ways to detect deception, and

[1] The terms deceptive behavior and lying behavior and variations of these are used interchangeably in this manuscript.

finally embark on the specific methodology we have used for our own research. The introduction ends with a brief overview of the rest of this dissertation.

Children's deceptive behavior

What do we know about the development of lying behavior?

We all lie on a daily basis (DePaulo et al., 2003; Talwar & Crossman, 2011) and learning to lie is an important "skill" for the development of adequate social behavior (Fu, Evans, Xu, & Lee, 2012; Ruffman, Murray, Halberstadt, & Vater, 2012; Talwar & Crossman, 2011; Talwar & Lee, 2002a, 2002b). This leads to an interesting paradox: while growing, children not only learn that lying is unacceptable behavior that can sometimes have more or less serious consequences, obviously depending on the type of lie itself; but simultaneously, the same adults (parents, teachers and other social agents in society) that condemn this type of behavior, also teach children that sometimes lying is an acceptable, and often a desired behavior (Talwar & Crossman, 2011). To learn and understand this dual nature of lies, to know when and where a lie is a preferred kind of behavior, is a very complex and challenging task for children, but also a fundamental one. While it would be considered inappropriate to be deceptive about a specific misdeed, there are other kinds of lies that are often even instigated by others, i.e. the so-called white lies. These are lies that people tell for the benefit of the other, or to "obey" certain social rules. These are often the small lies of daily life, such as*: "Thank you! This is the best meal that I've had for a long time"*, even if it was the worst one ever!

Interestingly, the ability to lie has been shown to happen within the same age period in a wide range of cultures (Talwar & Crossman, 2011); in particular, previous research showed that children start lying from a very early age, reportedly when they are 2.5/3 years old (Talwar & Lee, 2002a). The skill to deceive is obviously related to the extent to which a child is able to hide the fact that it is not telling the truth. Frequently, liars try to conceal their deceptive attempts from their verbal and nonverbal behavior (Talwar & Lee, 2002a; Vrij, 2000), hoping to avoid giving away cues that might signal their lies.

Over the years the interest in cues that point to deception has grown, even when our current insight into children's deceptive behavior is still far from complete (Talwar et al., 2009). Previous studies have been concerned with a range of research questions, from lie detection, specifically, to whether children and adults are able to detect children's lies (Talwar, Crossman, Gulmi, Renaud, & Williams, 2009), and questions regarding patterns on how and when different types of lies appear during childhood (Talwar & Crossman, 2011; Talwar & Lee, 2002b). As a possible resource for lie detection, research have been focusing on nonverbal features that children could possibly display when they are telling a lie, such as specific facial expressions (Swerts, van Doorenmalen, & Verhoofstad, 2013), verbal cues (Polak &Harris, 1999; Talwar & Lee, 2002a) or eye-gaze patterns (McCarthy & Lee, 2009).

At the same time, it is interesting to note that a few potentially relevant factors in children's deceptive behavior have not been explored yet. For instance, one specific gap in this tradition of research is related to the absence of studies into social factors that may come into play. Imagine the occurrence of lies in everyday life, when siblings or friends lie together to avoid punishment for inappropriate deeds. It is surprising that there are only a few studies that explore children's deceptive behavior in the presence of other people (e.g. Swerts, 2012), despite the fact that lying is often a social behavior that generally tends to occur in the presence of more than one interactional social partner.

In addition, nowadays, it is also more common that children do not only interact with human partners. Technology and socially intelligent agents are becoming part of our daily life. Social intelligent agents are designed to build relations with people, and to bring an added value to their life. Specifically, children get increasingly more exposed to this kind of technology already from a very young age, not only in playful settings (e.g. games), but also in more therapeutic settings, such as in cases where autistic children are helped with training programs to improve their social and learning skills (Parsons, 2015; Ramachandiran, Jomhari, Thiyagaraja, & Maria, 2015). Naturally, with the development of this type of artificial interactions, concerns have been emerging regarding the nature of the relationship children can build with artificial partners, as well as the trust children experience in their interactions with them. Moreover, from a development point of view, it is also important to understand what kind of ToM children have towards artificial agents, i.e., to what extent children feel that artificial partners can judge their mental state, and whether they perceive a difference between human and artificial partners.

More generally, despite the significant and broad number of studies that have been conducted in the last years regarding children's lying behavior, the findings are still often contradicting each other, and pointing to different directions, in particular when considering children's nonverbal and verbal cues to deception. A possible explanation for this is related to the lack of a consistent ecologically valid methodology to study children's deceptive behavior. From previous research, we can see first of all that there is a lot of variability between studies in terms of methodology, not only in the way lies are elicited, but also in the way deceptive behavior is analyzed (for an overview: DePaulo et al., 2003); secondly, a majority of the studies is conducted in rather artificial settings, such as a lab environment (e.g. Feldman, Jenkins, & Popoola, 1979) with the danger that these lies can be markedly different from the lies children would produce when not being observed by academic researchers, or in settings where lies are normal to occur.

The next sections present earlier research findings on deceptive cues and lie detection. Also given is an overview of the studies reported in this dissertation, with the respective relevant methodological considerations.

Deceptive cues and Lie detection

Apart from criminal and juridical reasons, one could also think of many situations in which parents, caregivers, or teachers would find it useful to know whether or not a specific child is trying to deceive them, even when these may mostly relate to innocent issues such as a stolen cookie or a fight with a peer. In the last years, there has been a particular interest in children's lying behavior (Talwar & Crossman, 2011; Talwar et al., 2009; Talwar & Lee, 2002b). Furthermore, the fact that a children's lying behavior is arguably connected to their cognitive development, in particular with their ToM, makes deception an even more interesting topic for research purposes.

In fact, most research shares the idea that there are certain verbal and nonverbal cues that may uncover whether one is lying or not, and that the accuracy levels of deception detection are higher if both nonverbal and verbal cues are taken into account (Vrij et al., 2004). However, most studies report that people usually perform poorly when asked to decide whether a child is lying or not, with accuracy levels around or slightly above chance level, which is comparable to the accuracy levels reported in adult studies (Bond & Depaulo, 2006; Edelstein et al., 2006, Vrij et al., 2006). For instance, a previous study showed that adult evaluators were able to recognize deceptive statements based on children's nonverbal behavior slightly above chance level, but could not distinguish truth-tellers (Talwar et al., 2009).

Moreover, lying can be a very demanding task, because maintaining a lie verbally consistent requires a significant cognitive effort, and lie-tellers also need to control their nonverbal behavior, and keep it coherent with the verbal one. Because of this inherent difficulty, lie-tellers often leak verbal and nonverbal cues to deception (DePaulo et al., 2003; Talwar & Lee, 2002a, 2002b; Vrij, Edward, Roberts, & Bull, 2000). Intuitively, this would be a more complex task for children because their ToM has not yet been fully developed. In fact, previous research showed that children leak more cues during their lie-tells than adults (Talwar & Lee 2002a; Evans, Xu, & Lee, 2011). Furthermore, studies regarding verbal cues also showed that young children lack a fully developed ability to avoid semantic leakage. Semantic leakage control is the ability to maintain consistence in the follow-up statements after the initial lie. Because this consistency is very difficult to sustain, children usually tend to show some semantic leakage during their lie-telling (Talwar, Murphy, & Lee, 2007).

Studies regarding children's nonverbal deceptive behavior showed evidence that there are differences between lie- and truth-tellers, though results between studies are not always consistent. For instance, some studies have linked more positive nonverbal cues with deception, such as smiles, confident facial expressions and a more positive tone of voice (Feldman et al., 1979; Lewis et al., 1989; Talwar & Lee 2002a). In contrast, another study found that young white lie-tellers displayed less big smiles, were less confident and relaxed, and appeared to be more serious and concerned than truth-tellers (Talwar & Lee, 2002b). Additionally, research showed that lie-tellers press their lips more often than truth-tellers (DePaulo et al., 2003; Talwar & Lee, 2002a). Other studies have focused on eye gazing behavior of young deceivers showing that deceivers looked significantly more often away compared with truth-tellers (McCarthy & Lee, 2009; Talwar & Lee, 2002a).

Body movement has also been suggested as a source for lie detection but, again, there are some contradictory statements about the usefulness of this feature. On the one hand, some literature states that when lying, people tend to constrain their movements, even though it is unclear whether these restrictions are related to strategic overcompensations (DePaulo, 1988), or to avoid deception leakage cues (Burgoon, 2005). In a similar vein, another study showed that movement is constrained during deceptive interactions in adults (Eapen et al., 2010). On the other hand, another study has suggested the existence of continuous fluctuations of movement in the upper face and in the arms during a deceptive interactions (Duran, Dale, Kello, Street, & Richardson, 2013), even when these differences only represented a trend as this study failed to find a significant difference in the total amount of movement between a deceptive and truthful condition. Moreover, when considering hand movements, another study reported that during deceptive interactions there is a tendency to do more speech prompting gestures, while truth-tellers do more rhythmic pulsing gestures (Hillman, Vrij, & Mann, 2012). Considering the fact that there are some weak indications that children tend to leak cues to deception, it is interesting to explore children's body movement during deceptive interactions. To the best of our knowledge, previous studies did not consider investigating children's deceptive behavior from a body perspective.

Several efforts have been made to develop efficient methods for deception detection, in particular focusing on the human face as the main source of cues for deception detection (Ekman, 2009; Swerts et al., 2013; Ten Brinke et al., 2012). Many of these methods are based on the Facial Action Code System (FACS), usually taken as the reference method for manually annotating facial movement and expressions (Ekman & Friesen, 1976), which have also been used as a basis for detecting facial cues to deception (Ten Brinke et al., 2012). The disadvantages of a manual procedure are that it is time consuming, and implies quite some technical training for the coders. More recently, automated approaches have been used for the study of deceptive behavior and lie detection. As mentioned above, not only automated movement analysis is starting to be used (Eapen et al., 2010; Duran et al., 2013) but also eye tracking has been used in several different ways. For example, it has been used to identify gaze patterns of adult players in a game situation, showing that the pupils tend to dilate more when they are sending deceptive messages (Wang et al., 2010). It was also used to study the eye-gaze patterns from experts of lie detection, showing that their gaze behavior tends to fixate in areas such as face and/or body (arms, torso and legs) (Bond, 2008). Additionally, other studies have been focusing on whether deception detection can be achieved by measuring physiological data, such as brain activity, galvanic skin conductance, and thermography techniques (Ding, Gao, Fu, & Lee, 2013; Kozel et al., 2005; Van't Veer, Stel, Van Beest, & Gallucci, 2014). Despite most of them showing promising results, these methods are quite intrusive, and not suitable for all contexts, especially when dealing with specific types of population, such as children. Therefore, results of these techniques are not further discussed in detail. Finally, the Computer Expression Recognition Toolbox (CERT), which is a software tool designed to detect facial expressions in real-time (Littlewort et al., 2011), could facilitate the research of nonverbal correlates of deception, but it is also highly dependent on the classification accuracy of these expressions. Another issue is that it is also not immediately clear how well it would work on children's faces because there are only a few studies that report on the analysis of facial expressions with this tool on children, so that there is still a lack of comparable datasets and related research (Grafsgaard, Wiggins, Boyer, Wiebe, & Lester, 2013; Littlewort, Bartlett, Salamanca, & Reilly, 2011).

Therefore, this dissertation contributes to improve our understanding of how children signal deception in their verbal and nonverbal behavior, and learn more about how these cues can be used as a source for lie detection. We use a multimodal approach, a combination of manual and automated techniques, to analyze children's behavior during deceptive interactions, while interacting with different types of social partners and social context. In the next section, a reflection on the methodological aspects of this dissertation is presented. In particular, this research will focus on the methods used to elicit children's deceptive behavior. Secondly, we will reflect on the type of multimodal approach used to analyze children's deceptive behavior that incorporated manual and automated techniques. And finally, we will address the perceptions studies used for lying detection.

Methodology

Studying children's deceptive behavior in naturalistic and authentic social settings is a difficult and challenging task. Inspired by the work of Talwar and Lee, (2002a, 2002b) who used playful, game-like scenarios, we have extended the basic idea underlying their paradigm by introducing new elements such as perception studies, contextual factors and the use of different conversation partners (detailed below). These modifications contribute to more natural environments which in turn should lead to more realistic human responses.

Also, despite the effort to improve lie detection techniques, previous studies still showed that this is still hard to achieve, both for humans (e.g. Talwar & Lee, 2002a), and for machines (Eapen et al., 2010; Duran et al., 2013).

Based on what is described above, this dissertation combines an innovative approach to investigate children's deceptive behavior. We conducted a number of experimental studies that not only combined production studies together with perception studies, but also used manual and automated techniques for analyzing cues (verbal and nonverbal) for lie detection.

In all studies, we aimed to elicit spontaneous lies from children, in a playful but also ethical way. The playful aspect is an important characteristic of these production studies because playful settings, such as games, are part of children's daily life. A game approach, which is engaging in its own nature, seemed to be the logical method. Therefore, these aspects were explored to elicit lies among children, with the advantage that game-based experiments are also more ethically appropriate for children, i.e., we aimed to elicit lies in children without causing feelings of stress and guilt. Finally, we aimed for a controlled setting that resembled normal contexts of daily life (e.g. schools), since lab contexts could have steered the lie elicitation procedure. This is more relevant with children, in which these contexts can induce more discomfort and stress, and influence their deceptive behavior.

In our production studies, children were invited to play different types of guessing games, which naturally induced them to lie in order to win the game. These games were played individually or in pairs, and with different types of interaction partners, either human or artificial, such as a virtual agent or a robot. Subsequently, in all studies we analyzed children's deceptive behavior (elicited during the production studies) with a multimodal approach, i.e., we combined perception studies for lie detection (with human judges), together with manual coding and automated measures to analyze children's deceptive behavior (verbal and nonverbal). Manual labeling protocols were developed for analyzing children's verbal and nonverbal behavior. For the verbal cues, we developed a protocol based on previous research that found specific verbal correlates of deceptive behavior (Benus et al., 2006; Bond & DePaulo, 2006; Ekman, O'Sullivan, Friesen, & Scherer, 1991). For the nonverbal cues, we also developed a protocol based on previous research (e.g. Talwar & Lee, 2002a) and results obtained using the Facial Action Coding System (Ekman & Friesen, 1976).

Regarding the automated analysis, we use a frame-differencing method to analyze children's body movement, and also to identify which areas of the body show possible nonverbal cues of deceptive behavior. This method is easy to use on pre-recorded videos, and generates heat maps that allow to easily identify the body regions where more movement happened. For the verbal cues, we perform a number of acoustic analyses, based on automated measures of certain prosodic features. Finally, we use an automatic analysis toolbox - Computer Expression Recognition Toolbox (CERT), to examine children's facial Action Units (AUs) (Littlewort et al., 2011). More specific details about the methodology can be found in the following chapters.

Finally, we also conducted perception studies with adults' observers to further understand how children's nonverbal behavior, specifically body movement and facial expressions, correlates with lie detection, i.e., if these signals are interpreted as cues that signal deception.

Overview

The overall aim of this dissertation is to examine children's deceptive behavior, and identify possible verbal and nonverbal correlates of deception, explore the effect of different types of social partners and of context, and investigate the extent to which deception can be detected by human judges based on children's nonverbal behavior. Therefore, this dissertation consists of 4 independent and self-contained studies[2]. These studies have been either published (chapter 2, chapter 4 and chapter 5), or submitted to international peer-reviewed journals (chapter 3).

Previous research has been focusing on children's nonverbal cues as potential source for lie detection (e.g. Swerts, van Doorenmalen, & Verhoofstad, 2013); however results are not always consistent between studies. As above described, a possible reason could be the lack of a systematic approach for lie elicitation, but also for the deceptive behavior analysis. The first study (chapter 2) investigates how easily it can be detected whether a child is being truthful or not in a game situation, and simultaneously it explores body movement as a cue for deception. We also introduce an innovative methodology – the combination of perception studies and automated movement analysis to explore children's lying behavior, that brings a more systematic approach to the analysis of deceptive behavior.

Additionally, studies regarding verbal cues also show that children, in particular young children are not the most skillful liars, and lack a fully developed ability to control semantic leakage (e.g. Polak & Harris, 1999; Talwar & Lee, 2002a.) The second study (chapter 3) focuses on the verbal cues and acoustic properties of children's lying behavior, which have not been explored to the full extent in previous research. In this study, we use once again a combination of methods to analyze children's deceptive speech, in particular characteristics that have been associated with deceptive behavior. In short, we use a manual protocol for analyzing specific disfluencies, such as pauses, together, with an automated method for analyzing specific acoustic properties, such as intonation or pitch. In this study, we use the dataset from the first study to analyze children's verbal cues as potential resource for lie detection.

These first studies focus on exploring children's verbal and nonverbal behavior during a lying situation towards a human partner. However, as already mentioned, children are starting to interact on a regular basis with artificial partners, and it is important to understand how children communicate and trust this type of partners. In particular, there are concerns regarding the nature of the relationship children can build with them. Moreover, artificial agents for children appear in different forms, with movements, shapes and behaviors that could be artificial or more human-like. Therefore, the third study (chapter 4) explores children's lying behavior towards personified robots, not only to improve child-robot interaction, but also to shed light on human deceptive skills in various contexts. Moreover, it is relevant to explore if children's deceptive behavior is affected by variability in the robot's appearance. In this study, we use a lie elicitation game based on the temptation paradigm. The use of this paradigm with robots as the main agents for lie elicitation is a very innovative aspect of this study. Children's facial expressions and speech related features are analyzed by using an automated approach.

Finally, it was also mentioned that is important to investigate lying behavior in the context of daily life. One important aspect is that lying behavior in daily life often occurs in the presence of the others, especially other peers. Therefore, the fourth study (chapter 5) not only aims to further explore how children's deceptive behavior proceeds towards a different type of artificial partner – social agents, but also how deceptive behavior is affected by the presence of a peer. This study focuses on the facial expressions that children exhibit while trying to deceive a virtual agent, but it also investigates

[2] There may be differences in statistical and methodological techniques in these 4 independent studies. These differences are generally due to differences in editorial policies and comments from the different journals/books.

whether such cues are affected by differences in the social context, i.e., whether a child is alone or co-present with another. The focus of the analyses is on the face because the face is often argued to serve as a 'window to the soul', i.e., facial expressions are often linked to a range of mental states (Ekman & Friesen, 1969; Swerts, van Doorenmalen, & Verhoofstad, 2013). We use an interactive lie elicitation game, in which the virtual agent is the one responsible for the lie elicitation. Children play the game in an individual setting, or together with a peer (co-presence). Once again, we use a combination of methods to examine facial expressions and lie detection. For the facial expressions, we use a manual method and an automatic recognition approach, while for the lie detection we conduct a perception study.

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2

Comparing a perceptual and an automated vision-based method for lie detection in younger children

Abstract

The present study investigates how easily it can be detected whether a child is being truthful or not in a game situation, and it explores the cue validity of bodily movements for such type of classification. To achieve this, we introduce an innovative methodology – the combination of perception studies (in which one uses eye-tracking technology) and automated movement analysis. Film fragments from truthful and deceptive children were shown to human judges who were given the task to decide whether the recorded child was being truthful or not. Results reveal that judges are able to accurately distinguish truthful clips from lying clips in both perception studies. Even though the automated movement analysis for overall and specific body regions did not yield significant results between the experimental conditions, we did find a positive correlation between the amount of movement in a child and the perception of lies, i.e., the more movement the children exhibited during a clip, the higher the chance that the clip was perceived as a lie. The eye-tracking study revealed that, even when there is movement happening on different body regions, judges tend to focus their attention mainly on the face region.

This chapter is adapted from:

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Introduction

A question which has intrigued many generations of researchers is whether and how one is being able to detect if the conversation partner is being truthful about the things he or she is claiming, or not. Apart from criminal and juridical reasons, this has been deemed relevant for educational and developmental purposes as well. In particular, there has been a specific interest in children's deceptive behavior, as it is considered to be an important milestone in a person's development. Typically, developing children at one point in their life "have to" learn to be able to lie, and this ability seems to emerge at similar ages, and to be ubiquitous across cultures (Talwar &Crossman, 2011).

These aspects of lying led to a series of studies into child- specific aspects of deceptive behavior (Fu et al., 2012; Ruffman et al., 2012; Talwar & Crossman, 2011; Talwar & Lee, 2002a, 2002b), such as: the development of lies in children (Talwar & Crossman, 2011;Talwar & Lee, 2002a), the types of lies that young children are able to tell after a transgression (Fu et al., 2012; Talwar & Lee, 2002a), the age difference in terms of deceptive behavior(Ruffman et al., 2012), and lie detection in children (Talwar et al., 2009).

Obviously, one could think of many situations in which parents, caregivers, or teachers would find it useful to know whether a specific child is trying to deceive them, even when these may mostly relate to innocent issues like a broken window, a stolen cookie or a fight with another child. Yet, lie detection in children has been shown to be very difficult (Talwar & Lee, 2002a; Talwar & Lee, 2002b). There has been a specific interest in nonverbal features (such as specific facial expressions or eye-gaze patterns) that children could possibly display when they are telling a lie. However, as we will show below, in a review of the literature, the evidence regarding the usefulness of such nonverbal features as markers of deceptive behavior is quite inconclusive. The variability in reported results could partly be due to (1) the kinds of features that have been investigated in terms of their cue value and (2) the techniques that have been used to detect such features. Moreover, it would also seem important that the lies that are investigated are natural and spontaneous, and in that way representative of the behavior children exhibit in their normal social contexts, which would render acted versions of lies less suitable for research purposes.

To introduce our own approach to detecting nonverbal cues in children's expressions, we first describe previous studies into deceptive behavior of children, then review previous findings of nonverbal correlates of lying behavior, and then say a few words about methods to (automatically) detect lies. We then embark on a description of our own study, which consists of a specific elicitation paradigm, two perception studies, and a variety of detection methods.

Related work

Children's Lying Behavior

Previous research suggests that children between 3 and 7 years old are quite good manipulators of their nonverbal behavior when lying, which makes the discrimination between truth-tellers and lie-tellers very difficult to accomplish (Lewis et al.,1989; Talwar & Lee, 2002a; Talwar et al., 2007). Most studies report that the detection of children's lies is around or slightly above chance level, comparable to what has been claimed for adults (Bond & Depaulo, 2006; Edelstein et al., 2006).

Yet, the extent to which children display nonverbal cues could be related to the kind of lie and to the circumstances under which these are told. There is evidence that children start lying from a very young age as early as 2 1⁄2 years old, and lie- tellers between 3 and 7 years old are almost indistinguishable from truth-tellers (Newton et al., 2000; Talwar & Lee, 2002a). Around three years old, children are already able to tell “white lies”, before that they mainly lie for self-serving purposes, such as: to avoid punishment, or to win a prize (Talwar & Lee, 2002b). Nevertheless, some research suggests that lie-tellers tend to exhibit slightly more positive nonverbal behaviors, such as smiles, relaxed and confident facial expressions, and a positive tone of voice (Lewis et al., 1989). However, other research suggests that children have poor control on their nonverbal behavior, which points towards opposite and conflictive directions of what has been previously reported (McCarthy & Lee, 2009; Vrij et al., 2004). For instance, a study has reported that children in the age of 7-9 years old show less eye contact when lying rather than when answering the truth while older children show longer eye contact, which is similar to what adults’ exhibit during a lying situation (McCarthy & Lee, 2009). Another study suggests a decrease of movement during a lie-tell, particularly on the hands and fingers (Vrij et al., 2004).

Furthermore, it has been reported that children tend to leak more cues to deception when they are more aware of their deceptive attempt: For example, children’s second attempts to lie (after having been told to repeat a previous lie) reveal more nonverbal cues in their facial expressions when compared to their first attempts (Swerts et al., 2013; Swerts, 2012). These findings, according to the authors, might be explained by the ironic effect of lying which states that lying becomes more difficult and most likely less successful, if a person becomes more conscious about his or her behavior when trying to intentionally produce a deceiving message.

Nonverbal Cues to Lying

Because people are often highly skilled deceivers, accurate lie detection is in general very difficult for human judges. This means that lie detection accuracy is usually around or slightly above chance level (Bond & Depaulo, 2006; Porter & Ten Brinke, 2008; Serras Pereira et al., 2014; Ten Brinke et al., 2012). However, most researchers in this field share the idea that there are certain verbal and nonverbal cues that may uncover whether a person is lying or not, and that the accuracy levels of deception detection are higher if both nonverbal and verbal cues are taken into account (Vrij et al., 2004). One line of research has been focusing on finding these cues by manipulating levels of cognitive load during a lie-tell, which makes lying more difficult, and probably facilitates the emergence of deception cues (Vrij et al., 2006; Vrij et al., 2008). Other studies have been focusing on specific nonverbal cues of deception, which can disclose some signals related to deception, such as stress and anxiety (DePaulo 1988; Bond 2012). In addition, one can sometimes distinguish truth-tellers from liars on the basis of particular micro-expressions, such as minor cues in the mouth or eye region (Ekman, 2009; Swerts, 2012), like pressed lips, and certain types and frequencies of smiles (DePaulo et al., 2003). However, by their specific nature, such micro-expressions are so subtle, and last only a few milliseconds that they might escape a person’s attention, so that deception detection tends to be a very difficult task. Another study suggests that emotional leakage is stronger in masked high-intensity expressions rather than in low-intensity ones, in both upper and lower face (Porter et al., 2012). Furthermore, the highest emotional leak occurred during fearful, whereas happiness shows the smallest emotional leakage. Despite the effort on finding deception cues on the face, results from many studies are frequently discrepant, and the supposed cues are often very subtle in nature (Feldman et al., 1979)

Additionally, it has been argued that eye gaze can also be a cue for deception, although the results from different studies are contradictory (Mann et al., 2002; Mann et al. 2004; Mann et al., 2013). According to one study, liars showed more eye contact deliberately than truth-tellers, whereas gaze aversion did not differ between truth-tellers and lie-tellers (Mann et al., 2013). In another study deception seems to be correlated with a decrease in blink rate, which appears to be associated with an increase of the cognitive load (Mann et al., 2002). However, in a different study, the opposite result has been reported, emphasizing that blink rate rises while masking a genuine emotion in a deceptive expression (Porter & Ten Brinke, 2008).

Body movement has also been suggested as a source for lie detection but there are some contradictory statements about the usefulness of this feature. On the one hand, some literature states that when lying, people tend to constrain their movements, even though it is unclear whether these restrictions are related to strategic overcompensations (DePaulo, 1988), or to avoid deception leakage cues (Burgoon, 2005). In a similar vein, another study measured the continuous body movement of people in spontaneous lying situations, and found that those who decided to lie showed significantly reduced bodily movement (Eapen et al., 2010). On the other hand, a study based on a dynamical systems perspective, has suggested the existence of continuous fluctuations of movement in the upper face, and moderately in the arms during a deceptive circumstance, which can be discriminated by dynamical properties of less stability, but larger complexity (Duran et al.,2013). Although, these distinctions are presented in the upper face, this study failed to find a significant difference in the total amount of movement between a deceptive and truthful condition. Moreover, when considering hand movements, another study found that lie-tellers have the tendency to do more speech prompting gestures, while truth-tellers do more rhythmic pulsing gestures (Hillman et al., 2012).

In sum, despite the fact that significant research about nonverbal cues for lie detection has been performed in the last years, results still seem to be very inconsistent and discrepant.

Automated Methods for Deception Detection

In the past few years, several efforts have been made to develop efficient methods for deception detection. Even though there is no clear consensus on the importance of nonverbal cues (see previous section), there has been a specific interest in human face as the main source of cues for deception detection (Ekman, 2009; Swerts et al., 2013; Ten Brinke et al., 2012). Many of these methods are based on the Facial Action Code System (FACS) (Ekman & Friesen, 1976), usually taken as the reference method for detecting facial movement and expressions, which has thus also been applied for detecting facial cues to deception (Ten Brinke et al., 2012). As a manual method, FACS is time consuming and rather complex to apply since it demands trained coders.

More recently, automated measures are being used to help researchers to understand and detect lies more efficiently and rapidly. An example, is the Computer Expression Recognition Toolbox (CERT) which is a software tool that detects the facial expressions in real-time (Littlewort et al., 2011), and it is based on the Facial Action Coding System (FACS)(Ekman &Friesen, 1976). It is able to identify the intensity of 19 different actions units, as well as 6 basic emotions. This automated procedure to detect facial movements and microexpressions can facilitate the research of nonverbal correlates of deception, but that obviously also depends on the accuracy with which these expressions can be detected and classified. One issue is that is not immediately clear how well they would work on children's faces.

Additionally, more novel automated measures are being used to investigate deception from different angles. Automated movement analysis is starting to be used for this purpose (Serras Pereira et al., 2014; Eapen et al., 2010; Duran et al., 2013). Eye tracking has also been used in several different ways for deception detection. Some studies (Wang et al., 2010) use eye tracking to try to define gaze patterns of liars versus truth-tellers; another option for using eye tracking systems is to study the eye-gaze patterns from the experts of deception detection. For instance, a study (Bond, 2008) has reported that experts on deception detection, when deciding about a message veracity, are perceptually faster and more highly-accurate, and seem to fixate their gaze behavior in areas such as face and/or body (arms torso and legs). Likewise, some other studies have been focusing on whether deception detection can be achieved by measuring physiological data, such as brain activity, galvanic skin conductance, and thermography techniques (Ding et al., 2013; Kozel et al., 2005;Van't Veer et al., 2014). However, these methods are quite intrusive, and not suitable for all contexts, especially when dealing with specific types of population, such as children.

Current Study

In sum, considerable work is currently being done on the development of efficient automated methods to detect deception, but there is still a tendency to discard the body as a source of possible nonverbal cues. In the future, such methods could be combined with what has been achieved via automated analysis of verbal cues (Benus et al., 2006) and gestures (Hillman et al., 2012) as potential sources for lie detection, since combining verbal and nonverbal cues have proven to be more accurate for lie detection (Vrij et al., 2004). Moreover, the inconsistency regarding the relevance and value of bodily cues for deception may partly be due to the use of different detection methods. This discrepancy is worthy to be investigated in a more systematic approach.

Finally, most of the research with children focuses on developmental questions of lying. In this study, we are interested in exploring the nonverbal cues of such behavior based on the assumption that children are less formatted by the social rules, and that they tend to leak more cues to deception when they are more aware of their deceptive effort (Swerts, 2012). Based on what is above described, this study presents a new approach to look into nonverbal cues of deception. It investigates how easily it can be detected whether a child is being truthful or not in a game situation, in which the lies are more spontaneous, and much closer to a normal social context. In addition, it explores the cue validity of bodily movements for such type of classification, by using an original methodology – the combination of perception studies and automated movement analysis.

Methods

Paradigm for Eliciting Lies

In order to elicit deception in young participants, we used a child-friendly procedure, which naturally induces truthful and deceptive statements from children. Inspired by previous work (Talwar & Lee, 2002a, 2002b; Talwar & Crossman, 2011), we developed a specific game, "Guess what I have behind the back?" which was presented to a child participant as a game in which an adult person (experimenter) had to guess what kind of object (fruit or animal) the child participant was hiding behind his/her back. This was achieved by a series of 9 simple questions (is it a fruit or an animal? What is its color, etc.) asked by the adult, and answered by the child. After the series of questions, the experimenter had to make a guess about what object the child was hiding. In the truthful condition, the child that hid the object replied to the questions about the object in a truthful way (truthful condition). In the two subsequent lying conditions, the child was encouraged to lie (by giving incorrect answers about the object, such as: saying that the object was orange when it was red) when answering the questions about the object. In order to achieve this, a confederate (another adult who was also present in the room) in between sessions prompted the child to lie in order to win the game and get a present as a reward. The arguments given by the confederate to elicit the lie were that the experimenter thought and said out loud that she was the best in this game. The confederate did this when the experimenter was absent, because she had to leave the room with an excuse (to pick up a phone call, or to pick up the next child that would play the game). The game was played twice in the deceptive condition, the only difference being that during the first lying condition the experimenter lost the game (after the final question) and guessed the object wrongly; while in the second lying condition, despite what the child described, the experimenter guessed the object correctly. The reason for having two lying conditions was inspired by previous results that children's second attempts of deceiving might reveal more nonverbal cues (Swerts et al., 2013). Each object (banana, apple, dog, and a giraffe) was attributed to a specific box, so that the experimenter always knew what was inside the box (even when the child was not aware that the experimenter in fact had this knowledge).

Participants

Forty-Two Portuguese children aged between 6 and 7 (M=6.38) years old enrolled in the 1st year of primary school participated. Two of the participants (a boy and girl) were removed from the sample because they refused to deceive the experimenter.

Procedure

Each game session lasted for about 30 minutes (depending on how wordy or fast a specific child was), and consisted of 5 distinctive moments: 1) Briefing, 2) Warming-up; 3) Truthful condition (Tc), 4) Lying conditions (Ly1 and Ly2) and 5) Debriefing. In the first phase (briefing), the experimenter explained the game to the children. In the warming-up, the experimenter played the game with the child, but in this case the roles were inverted: the experimenter picked an object and hid it behind her back. Then, the child had to ask questions about the object until the child was able to guess what the object was. After this training session, the actual experiment started (phase 3 and 4). First, the child played in the truthful condition, and then in the two lying conditions (see above). The session ended with a short debriefing in which a small reward was given. All the children enjoyed the game, and engaged easily (without any suspicion) on the lies.

Recordings

The games were recorded in high definition (HD) color using an HD video camera. Only the child was recorded (frontal view), while the experimenter, who was positioned next to the camera, was not recorded. Children were standing upright (Figure 1), against a white wall, to assure that all body movements were captured during the game play. The sessions with the children lasted between 52 seconds and 2.30 minutes.

Figure 1: The figure displays three different children playing the game during the experiment.

Ethical consideration

At the time of the data collection, there was no formal ethical approval from the university department, since only recently an ethical committee was set up. Nevertheless, a complete and rigorous process was respected and followed up during the realization of the experiments. First of all, we got approval from the school pedagogical director, and after this parents were also informed about the goal of the experiment. Secondly and prior to the experiments, signed consent forms from the children's parents were collected, in which it was asked permission for each child to participate and to be recorded. It also stated that the data and recordings of the children would be treated with confidentiality, and that would only be used for scientific purposes, such as articles and conferences presentations. In the end of the experiments, we also debriefed children and teachers (school staff).

Perception Test

A perception test was set up in order to explore whether judges would be able to guess whether the recorded children were saying the truth or were lying to the experimenter, based on their nonverbal behavior. From the 40 children, fragments of 30 children were selected for the perception test. For each child, we selected its responses to two consecutive questions ("is it a fruit or an animal?" and "what is the size of it?") in the three elicitation conditions, leading to a total of 90 clips. These two consecutive questions were chosen to have a balance between an open and close question, and because using all 9 questions would create extremely long stimuli for subjects, which would cause tiredness and distraction effects during the task performance. In addition, ten children were not included in the perception test because they took more than 20 seconds in replying to the above-mentioned questions, so that their responses became atypically long. Finally, the clips (without sound) were presented in a randomized order to small groups, consisting of 2-3 participants. The audio was removed, as we were primarily interested in the nonverbal expressions, and wanted to make sure that people could not rely on lexicon-syntactic cues when making their judgments. In addition, the judges were not informed about the relative frequency of truthful and deceptive utterances.

Participants

Twenty undergraduate students, between 18 and 25 years old (M=22.2, 15 women), were recruited from the online subject pool system from the School of Humanities of Tilburg University. Students participated for course credit.

Procedure

Upon arrival in the lab, each participant was informed about the aim of the perception test. Every participant also received a questionnaire for rating each clip. The questionnaire consisted of two simple questions: 1) Is this child lying? (yes/no); and 2). If you said "yes", where did you base your decision on? (feet/ legs/ shoulders/ face/ other, please specify). When responding to the second question, multiple answers were allowed. The perception test was administered as a Keynote presentation on an iMac. The perception test consisted of two phases – the warming-up phase in which 3 test clips (different from the ones used in the actual experiment) were shown and the respective part of the questionnaire was completed. After this the actual perception test started, in which 90 clips were presented and the respective questionnaire had to be completed. After each clip, there was a response interval of 12 seconds, which participants used to rate the clip. Each session was group-paced, though each participant had to do the task individually, and lasted between 35 minutes.

Results

The following results refer to the first question of the questionnaire – Is this child lying? (yes/no). For each clip, we first computed the percentage of times it had been classified as being deceptive by the judges. In an ideal situation with perfect classification results, this would give a response of 0 for clips of the truthful condition, and 100 for the two lying conditions. A one-sample t-test on these average scores revealed that they differed significantly from chance level (50%). In particular, the test showed that the scores were significantly below 50% for the truthful condition ($t(19)=-2.27$, $p= .05$), and above 50% for the two lying conditions (for the Ly1, $t(19)=5.01$, $p=.05$; and for Ly2 $t(19)=3.91$, $p=.05$).

In addition, a Repeated Measures Anova was conducted to compare the percentages of lie responses in each of the 3 conditions (Tc, Ly1 and Ly2). The analysis revealed a main effect of condition ($F(2,38)=38.80$, $p=.001$). Posthoc pairwise comparisons using the Bonferroni method showed that Ly1 (M=0.63, SD=0.11) and Ly2 (M=0.61, SD= 0.13) are significantly different from the Tc (M=0.43, SD=0.14, but not between themselves (Ly1 vs. Ly2). These results are depicted in Figure 2.

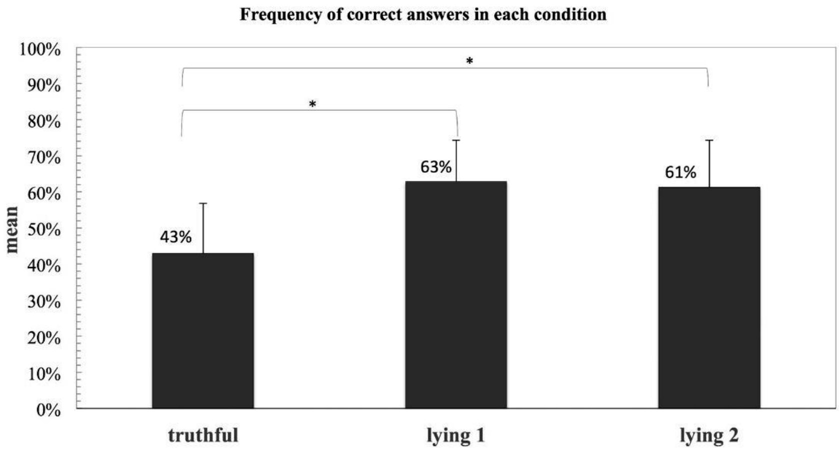

Figure 2: Frequency of lie responses for each of the three conditions (Tc, Ly1, and Ly2) in experiment 1.Statistical significant difference, $*p = 0.001$.

The goal of the second question- If you said “yes”, where did you base your decision on? (feet/legs/shoulders/face/ other, please specify), was to understand which part(s) of the body judges thought to be meaningful for deciding whether a child is lying or not. The relative frequency for each of the reported areas of the body was calculated for all the lying clips and perceived lies (the ones that actually were truthful but were reported by the judge as a lie). Results showed that participants reported that the face (75.62%) is the best assumed indicator of a lie, but feet (33.40%) and legs (30.35%) also were thought to be meaningful, while shoulders (16.63%) and other (12.71%) seemed to have less significant impact. Note that these observations were based on an overall analysis of the child data, even though it was clear that there were idiosyncratic differences between the participants (e.g. with some children being more expressive than others).

Automated Movement Analysis

In order to estimate the amount of movement in the video sequences and to identify which areas of the body show those nonverbal cues, a frame-differencing method was used. In this automated method, the absolute changes of (grey-level) pixel values in all pairs of subsequent frames are recorded and averaged per pixel over the entire video sequence yielding for each video a heat map showing the averaged changes during the sequence (see Figure. 3). A heat map is a visual representation in which numerical values, in this context average pixel changes, are represented by colors that are easily associated with an increasing quantity. In the present case, the colors reflect increasing temperatures ranging from black/brown (low), via yellow (intermediate) to white (high).

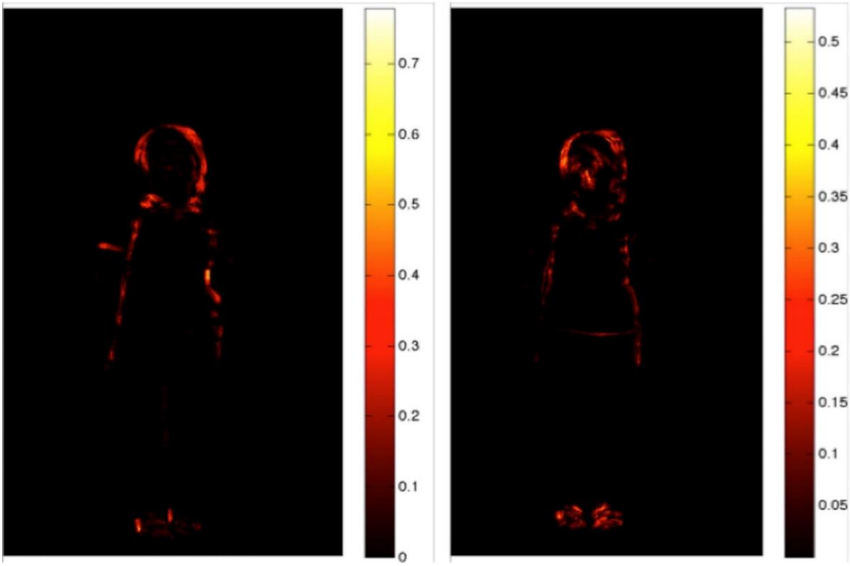

Figure 3: Illustration of the heat maps showing the outline of the body of a girl obtained for a truthful (Left) and a deceptive (Right) sequence in experiment 1. The unit of measure is the average pixel change, meaning that brighter colors indicate larger changes.

The video dataset used in the perception test was submitted to an automated computer analysis. In total there were 30 participants, resulting in 3 x 30 videos matrix. Each triplet consists of one video per condition: truthful (Tc), first lying (Ly1), and second lying (Ly2). The videos were cropped to retain the central region showing the interviewed child. The original size of 1920 x 1080 pixels was reduced to the central region of 801 x 1080 pixels. In three cases, small additional portions were removed due to movements caused by the experimenter and assistant.

In addition, to suppress spurious motions due to illumination compensation in the video camera, pixel changes were threshold. The threshold value was set at a fixed value of 25 (absolute pixel-change range: 0-255). All change values smaller than the threshold were set to zero. A visual assessment of all heat maps revealed that this thresholding effectively removed the spurious motions for all videos, while retaining the child-induced motions.

The estimated total movement is expressed in the absolute pixel change, which is obtained by taking the average of the average pixel change maps. Fig. 3 displays two heat maps of the average pixel changes obtained for a truthful (left) and a deceptive sequence (right). The first image (left side) is a truthful sequence whereas the right side corresponds to a lying sequence.

For the truthful condition, it is possible to observe that the movements occur mainly on the upper part of the body and the head, while the heatmap for the deceptive condition shows that the movements mainly occur on the head, face and feet. The brighter feet are due to their frequent movements during the video sequence.

Results

To assess the relation between the percentages of lie responses of the judges (from the perception test) in each of the 3 conditions and the amount of movement estimated by the frame-differencing method, a Spearman correlation analysis was performed. According to this analysis, there was a statistically significant correlation (r_s= .46, n=90, p < .001) between these variables suggesting that the more movement there is in a clip, the more likely it is that a clip is perceived as lie. Note that this first test did not specify whether a specific clip was in fact a lie or not, only that lie responses (whether correct or not) correlate with the movement measure.

A Wilcoxon signed rank test of the automated movement results for each condition (Tc, Ly1 and Ly2) was performed to assess whether these movement scores could distinguish each of the conditions. The comparison between the truthful and the first lying condition showed that the pairwise differences were not statistical significant (Z= -0.48, p= .61, r= 209). However, the results obtained by compared the truthful and second deceptive conditions showed a much clearer pattern, which suggested predominance of movement in the second deceptive condition, confirmed by the Wilcoxon signed rank test revealing the difference to be significant (Z= -2,56, p= .01, r= 108).

Additionally, a body-region based analysis was performed to further understand whether the movement analysis would reveal differences in performance for the different body parts. Three regions, namely head, trunk and legs were individually analyzed by (i) manually defining the horizontal boundaries (by taking the average frames of each video and interactively setting the horizontal boundaries by means of an interactive script) in each heat map that separate head from trunk and trunk from legs, and (ii) computing for each of the three regions the mean average pixel change value as a measure of amount of movement. A Spearman correlation analysis was conducted to evaluate the relation between the percentages of lies responses from the judges in each of the three conditions and the amount of movement per region (head, trunk and legs) calculated by this method. Results showed a statistical significance between each body region and the percentage of lies responses from the perception test (head: r_s = .38, n= 90, p= .001; trunk: r_s = .45, n=90, p< .001; legs: r_s = .40 n= 90, p< .001), which was in line with the previous analysis, indicating that the more movement there is in each of these regions, the more probable it is that a clip is perceived as lie. Furthermore, this analysis also showed that each region had a weaker correlation when compared to the overall movement correlation (r_s = .46, n= 90, p< .001), although the trunk correlation (trunk: r_s = .44, n=90, p< .001) was closer to the overall movement correlation.

To evaluate whether the movements scores in each of the three regions (head, trunk, and legs) could differentiate each of the three conditions (Tc, Ly1 and Ly2), a Wilcoxon signed rank test was conducted. For the three regions, the comparison between the truthful and the first lying condition showed no statistical significance on pairwise differences (head: Z= -0,11, p= .91; trunk: Z= -0.71, p= .48; legs: Z= -0.10, p= .30). On the other hand, when comparing the pairwise differences between the second lying condition and truthful condition for the three regions of the body, results showed a prevalence of movement in the second lying condition, (head: Z= - 2.21, p= .02; trunk= Z= -2.40, p= .01; legs= Z= -2.52, p= .01).

Finally, when comparing the movement differences between different regions in each of the conditions, it was possible to observe that for each of the three conditions, there was a statistical difference between the head and legs regions (Tc: Z= -3.73, p= .00; Ly1: Z= -2.28, p= .02; Ly2: Z= -3.32, p= .00), and between the trunk and legs (Tc: Z= -4.06, p= .00; Ly1: Z= -3.88, p= .00; Ly2: Z= -4.08, p= .00), suggesting a predominance of movement on the upper part of the body; while there was not a statistical significance between the movement of the head and the trunk in each of the three conditions (Tc: Z= -0.71, p= .48; Ly1: Z= -1.02, p= .31; Ly2: Z= -1.53, p= .12).

Second Study

Eye Tracking Study

The results from the first study showed that the face is assessed (by the judges) to be the best region to detect a lie, and that there was more movement happening on the body (in all the three regions) in the second lying condition.

In order to further comprehend these outcomes, an eye tracking study was setup. The main purpose was to understand whether the judges' gaze patterns - where they actually looked - when deciding whether one was lying or not would be in line with their own intuitions, especially in view of the fact that other body parts could in principle also be informative. And, to see if these gaze patterns were congruent with what was previously reported on the first perception test, mainly if the face is the principal region to where they looked; or if there is less conscious observation behavior while looking at different parts of the children's body.

To achieve this, judges' eye movements were recorded with an SMI Hi-Speed Eye-Tracker with a sample rate of 250 Hz, on a new set of participants who also did the perception task (see below).

Stimuli

Due to the fact that eye-tracking studies are very demanding to the eyes, the number of clips used for this experiment was shortened. From the 30 children from the first perception study, 20 randomly children in the three elicitation conditions (Tc, Ly1 and Ly2) were selected, leading to a total of 60 clips. Finally, the clips (without sound) were presented in a randomized order to participants.

Participants

Twenty-Seven Dutch undergraduate students, between 18 and 42 years old (M= 22.1, 25 women), were recruited from the online subject pool system from the School of Humanities of Tilburg University. Students participated for a half course credit. Eight students were excluded from the sample, either because they did not meet the experiment requirements, or because at a certain point of the experiment, they could not get calibration or validation accuracy lower than 1.5 degrees of freedom in both axis (X, Y).

Procedure

Upon arrival in the lab, each participant was informed about the aim of the test. The perception test consisted of two phases – the warming-up phase in which 3 test clips (different from the ones used in the actual experiment) were shown, so that the judges could get acquainted with the experiment setup. After this, the actual perception test started, in which 60 clips were presented. Subsequently, the participants had to answer (on the screen) always the same question: 1) Is this child lying (yes/no). Each session was self-paced, and lasted between 30 to 40 minutes, with a break of 5 minutes in between. The break was created as an attempt to eliminate the possible fatigue of the eyes that such system can cause. There were two 9-point calibrations, one in the beginning of the experiment, and the second after the break. There were also 3 validations, one after the warm-up phase, the second one in the middle of the first part, and the last one in the middle of the second part. The accepted gaze position error was below 1.5 degrees of freedom. Nevertheless, due to the length of the experiment that occasionally caused tiredness in the eyes, each attempt for calibration and/or validation was repeated maximally 3 times; otherwise, participants were excluded from the experiment.

Apparatus

The perception test was administered on a Dell screen (1650x1050) with an SMI RED 250 eye tracker, running at 250Hz. The experiment was setup in Experimenter Suit 360, which is a software component of SMI-Tracker.

Data Processing

The eye gazing data was processed in BeGaze 3.5. For each clip, four subjacent areas of interest in the children's body were drawn. These areas had to be manually defined for each clip, mainly because most children had different sizes, and were positioned in slightly different areas of the screen. These areas corresponded to the same body regions that were used for the second question from the first perception test (- If you said "yes", where did you base your decision on? feet/legs/shoulders/face). The first area contained the child's head and neck, the second area covered the child's upper body (from the shoulders to the hips), the third area was defined by the legs (from the hips to the ankles), and the fourth area enclosed the feet. Additionally, a fifth area on the left low corner of the screen was defined, and considered to be noise (occasionally the hands of the experimenter appeared on that area). Also, print-screens of each clip were made, preserving the same size and image quality as the original clip, so that the areas of interest could be exported on top of each print-screen, and keep the right position on the children's body. Finally, the gaze data from the eye-tracker, the areas of interest and the print screens were exported to Fixation (Cozijn, 2006).

In Fixation, a manual review of all fixations and a reassignment of some fixations into the respective areas of interest was made; the reason for this was related to the fact that the movement in the clips is not contemplated on a print-screen of the clips (which are static images of the clips). Therefore, when exporting all the data into Fixation, there were some fixations that fell very close to the areas of interest, but not exactly in the areas of interest, and those required a manual correction and reassignment for the respective area of interest, if that was the case. Fixation allows such reassignments to be made.

Results

In order to verify the lie detection accuracy of this new set of judges, and confirm if they behaved similarly to the first group of judges (first perception test), a similar analysis for the question – Is this child lying? (yes/no) was performed. Based on the percentage of times that each clip had been classified as being deceptive by the judges, a one-sample t-test showed that the scores were significantly below 50% for the truthful condition ($t(18)=-4.11$, $p= .05$), and above 50% for the two lying conditions (for the ly1, $t(18)=1.01$, $p=. 05$; and for ly2 $t(18)=2.56$ $p=. 05$).

When comparing the percentages of lie responses in each of the conditions (Tc, Ly1 and Ly2), a Repeated Measures Anova revealed a main effect of condition ($F(2,36)=17.29$, $p< .000$). Post hoc tests using the Bonferroni correction revealed Ly1 (M=0.54, SD=0.16) and Ly2 (M=0.57, SD= 0.11) were significantly different from the Tc (M=0.39, SD=0.12, but not between themselves (Ly1 vs. Ly2). These results are depicted in Figure 4.

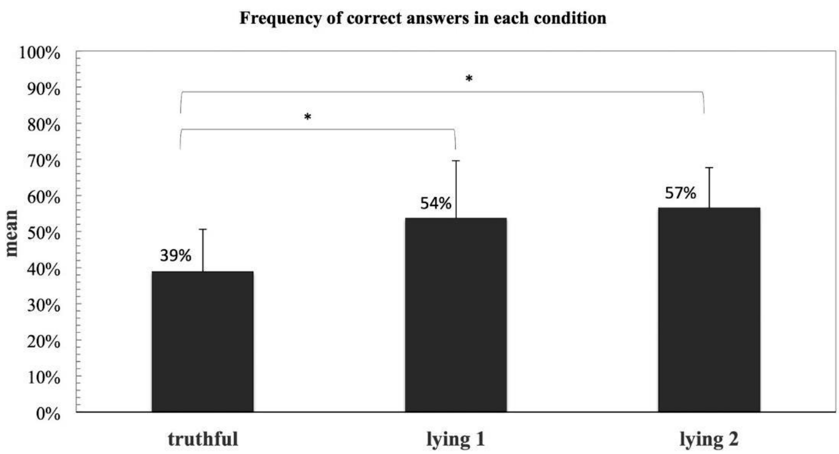

Figure 4: Frequency of lie responses for each of the three conditions (Tc, Ly1, and Ly2) in experiment 2. Statistical significant difference, $*p < 0.001$

To compare the gaze duration in each of the four body regions (head, trunk, legs and feet) for the three conditions (Tc, Ly1 and Ly2), a Repeated Measures Anova was performed. Table 1 shows the gaze duration for the 4 different regions (head, trunk, legs and feet). Results revealed that judges gazed significantly more often to head region ($F(1,19)=96.52$, $p= .001$) than to other body parts, but there was no interaction between the three conditions and each of the four regions, neither between each region and the quality of the observers' rates (good vs. bad judgment regarding the rate accuracy). For the head region, post hoc tests using the Bonferroni correction revealed that Tc (M= 126.9, SD= 46.6), Ly1 (M= 106.5, SD= 28.4) and Ly2 (M=124.9, SD=28.5) were significantly different from other body regions Tc (M= 45.4, SD= 32.1), Ly1 (M= 34.9, SD= 31.1) and Ly2 (M= 42.1, SD= 30.9). In other words, even when our previous movements analyses suggested that cues to deception appear to be distributed over the whole body (head, trunk and feet), the judges only seemed to pay attention to cues that appeared in the child's facial area. Note, however, that the eye fixations on the head do not imply that the judges did not notice cues in other body parts, but it does suggest that the face is intuitively used as the primary resource for lie detection.

Table 1 The average of the gaze duration in each of the four regions in seconds.

Body Regions	Tc Mean (SD)	Ly1 Mean (SD)	Ly2 Mean (SD)
Head	126.9 (46.6)	106.5(28.4)	124.9 (28.5)
Trunk	35.6 (28.4)	27.4 (27.8)	31.3 (29.6)
Legs	3.02 (4.03)	2.15 (2.89)	4.70 (4.81)
Feet	0.759 (1.03)	0.64 (1.11)	0.41 (0.44)

The heat map in Figure 5 represents the judges' fixations in each of the conditions, which clearly illustrates that independent of the condition (Tc, Ly1 and Ly2), the main hot spot is on the children's face, meaning that that was the region where judges spent the majority of the time. Likewise, there were smaller hot spots in other parts of the body, such as legs and feet, suggesting that the judges looked at those regions when there was some movement happening there, even when to a far lesser extent. Finally, a similar result is also depicted in the focus map on Figure 6. The focus map shows the regions that were less visualized (covered in black) by the judges, i.e., that had less fixations in each of the three conditions (Tc, Ly1 and Ly2), which also illustrates that the face was the most prominent region, but once again there were also uncovered areas in the legs and feet regions.

Discussion of Results

Previous studies have shown that results regarding lie detection in children are very discrepant, and often (self) contradictory. These inconsistencies might not only be explained by the idiosyncrasy of lies, but also because there is such variability in the methods used to investigate it. In addition, as already pointed out, the tendency to discard the body, and the relevance of bodily cues may also contribute to these facts. As an attempt to address these issues, the present study uses a novel and systematic approach to look into non-verbal cues to deception, by combining a game elicitation paradigm for lie elicitation with an original methodology of perceptual and automated vision-based analyses. As a basis for our study, we used behavioral data that were obtained through a game-based procedure, that worked extremely well with our participating children, since a vast majority of them spontaneously engaged in the game and were eager to lie in order to win. However, we have only looked at children who were between 6 and 7 years old, which naturally begs the question how their behavior compares to that of people in different age ranges. There is evidence in the literature that suggests that children's lying behavior develops with age (Talwar and Crossman, 2011), probably related to their more general cognitive and moral development, but details are lacking on how exactly their lying behavior evolves toward adulthood. To the best of our knowledge there are actually no studies exploring the differences between adults and children's lying behavior. But while it is clear that the research questions regarding such developmental patterns are interesting and relevant for the study of cognitive and moral development in general, it is not self-evident what paradigm would work in similar ways with participants in different age groups. Our current game-based elicitation procedure was tuned to younger participants, but would literally seem to "childish" to be used with adult participants, whereas other paradigms may work well with adults, but may not be child friendly. An important experimental challenge for the future is therefore to find a method that is able to obtain comparable behavior from children and adults in truthful and deceptive contexts. Our research has led to a number of interesting results. First, it is noteworthy to point out that in both studies, participants were able to distinguish truthful clips from lying clips above chance level, although the percentage of accuracy for lie responses was lower in the second study, which could be due to the smaller amount of clips presented to the judges (on the first study 90 clips were shown vs. 60 clips in the second study), and the fact that the eye gaze equipment may have made the task more demanding. But overall, the accuracy levels are very similar to what has been reported in some of the literature studies (Edelstein et al., 2006; Porter and Ten Brinke, 2008; Swerts et al., 2013; Serras Pereira et al., 2014). The automated movement exhibited during a clip, the higher was the chance that the clip was perceived as a lie. Furthermore, a similar but less strong correlation was found in the body region analysis, which suggests a "gestalt effect" (the whole is more than the sum of its parts) – the more movement the children exhibited in the three different body regions (face, trunk, and legs) in the clips, the more likely it was that it was also perceived as a lie, but less likely when compared with the overall movement correlation. These results contradict partly the argument that people tend to constrain their movements, and show less body motion when lying, as reported by previous studies (DePaulo, 1988; Burgoon, 2005; Duran et al., 2013). However, these previous findings are related with adult's deceptive behavior, and should be carefully considered when comparing to children's' deceptive behavior, since these differences might be related to the age difference. Moreover, this method suggests an interesting difference in nonverbal behavior between the children's first and second attempt to produce a lie. While the overall amount of movement appears not be distinct from the one in the truthful condition during the first attempt, there does appear to be a difference during the second attempt. Furthermore, when focusing on specific regions of the body, it appears that this behavioral pattern generalizes to different body parts. During the second attempt to produce a lie, there is a significant increase of movement in the head, trunk, and legs that distinguish it from the truthful condition, which does not happen between the truthful and the first lying condition. Additionally, there is more movement happening on the trunk and head when compared with the legs, which seems to indicate that most of the movement happens in the upper part of the body. The non-significant movement differences between the head and the trunk might be explained by this fact, and it might indicate that the head and trunk work as a full unit/block in terms of movement expression. In any case, these findings appear to be in line with earlier finding (Swerts et al., 2013) that a child's awareness of the fact that it is producing a lie leads to the ironic fact that it becomes harder to hide non-verbal cues to deception: They tend to leak more cues because of the irony effect. Moreover, the heat map and the focus map visualizations from the movement analysis point toward the same body regions in which the judges, from the first study, thought they based their decision, when deciding whether a clip is truth or a lie. The face (75.62%) was the most often reported region but the feet (33.40%) and legs (30.35%) also seemed to play a significant role. These findings are also supported and corroborated by the eye-tracking study (second study). Although the body tends to leak more movements during a deceptive situation, it seems that the judges mainly focus on the face when deciding if one is being truthful or not. These findings are partly in line with previous research (Bond, 2008). Lastly, the eye-tracking study revealed that, even when there is non-verbal leakage (movement) happening in different body regions, as illustrated by the heat and focus maps (Figures 5 and 6), it seems that judges tended to limit their main focus of attention to only a limited part of the body, namely the face region. Yet, what is not clear is whether the judges chose to ignore (in a more or less conscious way) these non-verbal leaks, or if the movement on those regions is not informative enough for making the decision, or if the judges use their peripheral vision toward those regions, when looking to the face. To further understand these phenomena and to clarify whether the movement on the different regions is informative enough for lie detection, we are currently conducting new perceptive studies where only parts of the body (face, body and feet) are shown to participants.

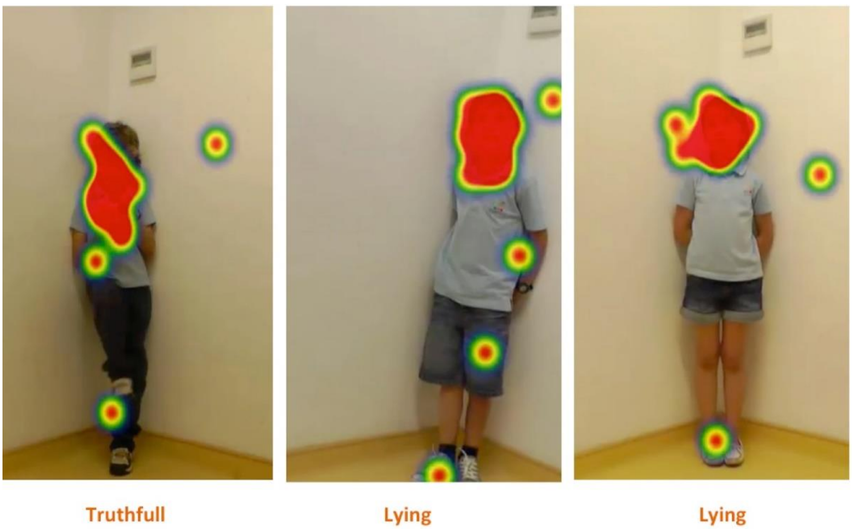

Figure 5: Illustration of a heat map showing all the judges' fixations in each of the conditions three conditions (Tc, Ly1, and Ly2).

Figure 6: Illustration of a focus map showing the regions (in black) that had fewer fixations by all the judges in each of the three conditions (Tc, Ly1, and Ly2).

LIMITATIONS

We would also want to discuss some of the limitations of the current study. The first one is related to the experimenter role. The data were obtained through a paradigm in which a "human" experimenter participated, very much in line with previous studies in this area (see e.g., Talwar and Lee, 2002a,b). Although the experimenter tried to be as consistent and neutral as possible throughout the entire study, she is obviously not acting like a robot that uses a limited and controlled set of interaction strategies. There are several aspects that contribute to this factor: first of all, in the interactive setting, the experimenter is likely to adapt to characteristics and perceived personality of the interacting child. In the present study, there was obviously quite some variability in the way the children behaved, so that it becomes almost unavoidable that these, maybe even unconsciously, have influenced the way the experimenter interacted with those children. For example, think about children that are friendlier and smile more during their interaction, versus children that were very quiet and shy throughout the entire game. These factors may have influenced the way the experimenter behaved. One could consider using a robot or an avatar instead of a human experimenter like in previous studies (e.g., Swerts, 2012; Serras Pereira et al., 2016) as this would allow control over the experimenter role, which might conversely introduce a certain risk that the interaction would become more artificial, and thus leading to data that are not ecologically valid. More work is needed here. Furthermore, we have limited the study to Portuguese children without really controlling for gender, so that it would seem obvious to extent the study to include other factors, such culture and age, into the analyses, to explore whether these have an effect on children's behavior. Finally, there are also technical limitations. For instance, the eye-tracking study showed that judges tend to focus on the facial area while trying to detect a lie. While this suggests that observers were primarily looking for behavioral cues in that bodily region the method does not allow to exclude the possibility that observers were detecting cues in other bodily areas as well through more peripheral vision. A more sophisticated method that takes such peripheral viewing into account would therefore seem useful. Along the same lines, our frame-differencing method has given us first crude evidence that bodily movement is used as a cue by observers for lie detection. This method could be fine-tuned so that it is able to provide more exact details on patterns in bodily motions that are associated with truthful and deceptive behavior.

Conclusion

In sum, the present study examined how easily it can be detected whether a child is being truthful or not in a game situation, and it explores the cue validity of body movements for such type of classification. To accomplish this, an original methodology was used, i.e., the combination of perception studies (in which one uses eye-tracking technology) and automated movement analysis. Film fragments from truthful and deceptive children were shown to human judges who were given the task to decide whether the recorded child was being truthful or not. Results showed that, in a set of perception studies, judges were able to correctly distinguish truthful clips from lying clips. Despite the fact that the automated movement analysis for overall and specific body regions did not yield significant results between the experimental conditions, a positive correlation between the amount of movement in a child and the perception of lies was found. This means that the more movement the children exhibited during a clip, the higher the chance that the clip was considered a lie. Finally, the eye-tracking study revealed that judges tend to focus their attention mainly on the face region, even if there is movement happening in different body regions as well. Finally, contrary to what earlier research has stated, it seems that body movement is a good source for the detection of deception. The frame differencing method used in the current study proved that children tend to show more body movement during a lie-tell. However, a more sophisticated and robust movement analysis is desired for future studies. This type of analysis will allow to further understand and differentiate the type of body movement during a deceptive situation. Also, in order to further understand which are the facial expressions that correlate with children’ lying behavior, a systematic and automated facial expressions analysis is desirable. Being able to identify these facial expressions can be an important step toward efficient lie detection. Furthermore, it would be useful to understand how children’s verbal behavior during deceptive interactions correlates with deception detection. In particular, how disfluencies like pauses or/and acoustic properties, such as pitch and intonation relates to deception. Finally, note that the child participants in our study were Portuguese, whereas the judges were Dutch. In the future, it would be nice to explore whether there are any cross-cultural differences in the expression and detection of deception.

Acknowledgments

Part of this work is based on our previous work: Serras Pereira, M., Postma, E., Shahid, S., & Swerts, M. (2014). Are You Lying to Me? Exploring Children’s Nonverbal Cues to Deception. In 36th Annual conference of the Cognitive Science Society (pp. 2901–2906).

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3

Acoustic properties of children's speech in truthful and deceptive interactions

Abstract

The present study investigates acoustic properties of children's speech in deceptive and truthful interactions. The analyses were based on recordings obtained through a lie elicitation game in which children were either being truthful or lying about an object hidden behind their back. The game was played in a truthful condition and in two lying conditions (Ly1 and Ly2). Results revealed that Long Pauses (LP) and Filled Pauses (FP) are less frequent in the deceptive interactions compared to the truthful ones. Moreover, Prolonged Words (PLW) occurred more often in deceptive speech than in truthful speech. Lastly, an acoustic analysis showed that children's deceptive speech had higher levels of intensity but also less jitter variation when compared to truthful utterances.

This chapter is adapted from:

Serras Pereira, M., Shahid, S. and Swerts, S. (2017). Acoustic properties of children's speech in truthful and deceptive interactions. Palgrave Handbook of Deceptive Communication (accepted for publication).

Introduction

Many parents share the experience of having the suspicion that their child is lying about a specific misdeed, basing that impression on the observation that their son or daughter is acting in a strange fashion. There is definitely a cookie missing from the pot, and when confronting their beloved child about this specific fact, there is something in their behavior, which tells them that the thief is standing right in front of them, even though the latter is denying having done something wrong. Most research into deceptive interactions, in particular studies focusing on children, has been exploring specific nonverbal characteristics of children during the deceptive act, as well as the verbal content of their utterances, to see whether they exhibit certain characteristics that set them apart from truthful statements. In the current study, we will look into auditory characteristics, and explore whether these can reveal cues that can distinguish children's truthful from deceptive utterances. We first review previous studies regarding children's lying behavior, and about deceptive speech in general. We then present our own study where we first describe the lie elicitation paradigm, then the manual coding scheme used for analyzing the different types of speech disfluencies, and the automatic analysis for the acoustic properties. Finally, we present our results, and finish by reflecting on these and presenting future directions of research.

An important reason for the scientific interest in the deceptive behavior of children is that their lying behavior has been considered to be a defining landmark in their social and cognitive development. Children with a typical development are assumed to have the "skill" to deceive at a certain stage during childhood, where this has even been viewed as a prerequisite for the acquisition of adequate social behavior (Fu, Evans, Xu, & Lee, 2012; Ruffman, Murray, Halberstadt, & Vater, 2012; Talwar & Crossman, 2011; Talwar & Lee, 2002a, 2002b). Interestingly, the ability to lie has been shown to happen around the same period of development in a wide range of cultures investigated (Talwar & Crossman, 2011). The similarity in the acquisition of deceptive behavior in growing children is believed to shed light on universal properties in the development of Theory of Mind (ToM) (Talwar, Gordon, & Lee, 2007; Talwar & Lee, 2008), working memory (Alloway, McCallum, Alloway, & Hoicka, 2015) and executive functioning skills (Lee, 2012). The skill to deceive is obviously related to the extent to which a child can hide the fact that it is not telling the truth. So, accordingly, there has been quite some work into lie detection. These studies have been concerned with a range of research questions, for instance, related to the problem as to whether children and adults are able to detect children's lies (Talwar, Crossman, Gulmi, Renaud, & Williams, 2009), and questions regarding patterns on how and when the different type of lies appear during childhood (Talwar & Crossman, 2011; Talwar & Lee, 2002b). As a possible resource for lie detection, researchers have been focusing on nonverbal features that children could possibly display when they are telling a lie, such as specific facial expressions (Swerts, van Doorenmalen, & Verhoofstad, 2013), body movement (Serras Pereira, Cozijn, Postma, Shahid, & Swerts, 2016) or eye-gaze patterns (McCarthy & Lee, 2009). Furthermore, studies regarding verbal cues also show that children, in particular young children are not the most skillful liars, and lack a fully developed ability in terms of semantic leakage control. Semantic leakage control is related to the phenomenon that in order to produce a successful lie, children must not only produce a false statement, but also need to maintain consistence in the follow-up statements (after the first lie). This consistency is very difficult to sustain, so that children usually tend to show some semantic leakage during their lie-telling (Polak &Harris, 1999; Talwar & Lee, 2002a).

There are several situations in which it would be useful to know if a child is trying to deceive, not only in marked settings, such as a robbery or other serious offences which may be less likely to happen with children, but also in simple occurrences of daily life, such as when children lie about their deeds at school, or towards their parents. Hence, being able to distinguish deceptive speech from non-deceptive speech is very relevant for practical purposes of daily life, but also for criminal and juridical reasons, and educational and development purposes. The current study focuses on speech-related features of children's deceptive behavior, which have not been explored to the full extent in previous work.

Related work

Children lying behavior

In line with claims based on ToM, previous research has shown that in order to be a successful lie-teller, children not only need to be able to recognize their own mental state, but also that of another person (i.e. the person to whom they are lying) whose mental state they want to manipulate (Polak & Harris, 1999;Talwar & Lee, 2002a). That implies that they also need to learn how to control their nonverbal and verbal behavior, as they need to maintain consistency between the first produced false statement and the follow-up statements, and need to hide possible correlates of deception in their body language (Talwar & Crossman, 2012).

Earlier research has found that children's ability to lie appears as early as 2 ½ and 3 years (Lewis et al., 1989; Newton, Reddy, & Bull, 2000), and improves with age, since according to a previous study lie-tellers between 3 and 7 years old are already very difficult to distinguish from truth-tellers, specifically when only looking at their nonverbal behavior (Talwar & Lee, 2002a). Children at this later age are already able to partly conceal deceptive cues in their verbal and nonverbal behavior during a lie tell, which makes lie detection a very difficult task with detection levels accuracy around chance level (Bond & Depaulo, 2006; Edelstein, Luten, Ekman & Goodman, 2006).

However, the findings from earlier studies regarding the children's ability to control their nonverbal behavior during a lie-tell are quit inconsistent (Feldman, Jenkins, & Popoola, 1979; Lewis et al., 1989; McCarthy & Lee, 2009; Vrij, Akehurst, Soukara, & Bull, 2004). On the one hand, a previous study associated more positive nonverbal cues with children's lying behavior, such as smiles, confident facial expressions, and positive tone of voice. This suggests that children tend to mask their lies with more positive nonverbal behavior (Feldman et al., 1979). On the other hand, another study showed that nonverbal cues, such as body activity and facial expressions, did not allow to differentiate between children who lied versus truth-tellers (Lewis et al., 1989). Still other studies show that children have less control over their nonverbal expression during a lie-tell, and show features that are not specifically positive in nature (McCarthy & Lee, 2009; Vrij et al., 2004). For instance, children between 7-9 years old more often resumed their eye contact during a lie-tell than older children (McCarthy & Lee, 2009). Additionally, some studies suggest that the more aware children are about their deceptive effort, the more nonverbal cues they tend to leak (Serras Pereira et al., 2016; Swerts et al., 2013). In particular, when children were explicitly asked to repeat a lie, it turned out that they showed more nonverbal leakage during their second attempt of lie. This can be explained by the so called ironic effect of lying – if people are more aware of their behavior when lying, it becomes more difficult and they probably get less successful to maintain the lie, and therefore more nonverbal cues are leaked (Serras Pereira et al., 2016; Swerts et al., 2013).

Furthermore, as mentioned before, studies regarding verbal cues on children's deceptive behavior have shown that young children lack semantic leakage control (Polak & Harris, 1999; Talwar & Lee, 2002a). Particularly, one of these studies assessed indirectly preschooler's ability for semantic leakage control. In short, they asked children between 3-5 years old about characteristics of a toy that they previously denied having looked at or touched. Results show that most of the children were not able to simulate that they had not seen or touched the object, and leaked information that they could only know if they had looked at the toy beforehand (Polak &Harris, 1999). Likewise, another study examined lying behavior in children between 3 and 7 years of age (Talwar & Lee, 2002a). In a similar vein, children were instructed to not peek at the toy hidden behind their back. Results show that when confronted with the question whether they had peeked at the toy, only half of the 3-year-old children confessed their transgression, and most of the older children denied it. Moreover, most of the children showed poor semantic leakage control, and adult judges who were asked to identify the lie-tellers based on their verbal statements (made in the context of the lies), could correctly identify those children who were telling a lie. The results also show that children between 3-5 years old find it hard to maintain their discourse consistent and coherent during a deceptive act. However, when becoming 6-7 years old, half of them are able to keep at least a certain level of semantic (leakage) control.

In general, these studies show that children can lie from a very young age. However, they are still very inconsistent in keeping their lies coherent, and leak significant verbal and nonverbal cues during their lie-tells.

Deceptive Speech

Apart from research into verbal cues (the words people use), and nonverbal characteristics, there has been some interest in analyses of audio features that can be measured from the speech signal, albeit that prior work – to the best of our knowledge - has only been focusing on adult's speech. In general, it is believed that these signals as well may cue deceptive speech, specifically they could reveal signs of emotional states, tension, stress and /or cognitive load, which are often associated with deception. Particularly, intonation may be of interest in this respect (Rodero, 2011). For instance, there are studies that show that pitch may signal specific emotions, such as joy, sadness, anxiety or calmness (e.g. Rodero, 2011, as well as many others). Moreover, deception has been associated with emotional arousal, which would make the set of such audio features a likely candidate to reveal deceptive speech. In fact, some acoustic correlates of speech, such as pitch, vocal tension, and certain disfluencies have indeed been associated with deception detection (Benus et al., 2006; Bond & Depaulo, 2006; Ekman, O'Sullivan, Friesen, & Scherer, 1991). For instance, a study in which young adults were asked to describe pictures either in a truthful way, in a deceptive way or in suspicious manner, shows that deception caused an increase in F_0, and also an increase in the number of pauses and words (Anolli & Ciceri, 1997). Another study, in which vocal samples were perceptually and acoustically analyzed, demonstrates that deceivers showed a wider range of intensity, and an increase in pitch variance (Rockwell, Buller, & Burgoon, 1997). However, another study in which deceptive, truthful and speech from a control condition was elicited from speakers in an interview setting, shows no relation between deceptive speech and certain acoustic measures, such as F_0, overall amplitude and vowel formants (F_1, F_2 and F_3)

(Kirchhübel & Howard, 2013). Given that these previous studies on acoustic properties have all been focusing on adult speech, it would seem relevant to explore whether children show any acoustic patterns in deceptive utterances.

Furthermore, significant research has been conducted in order to understand the role of disfluencies in speech, specifically regarding the function of pauses and fillers in adults and children speech (Esposito, Marinaro, & Palombo, 2004; Krahmer & Swerts, 2005; Swerts, 1998). In particular, disfluencies have been associated with adult's deceptive behavior. For instance, Loy, Rhode and Corley (2016) developed two experiments to investigate the listener's judgments about whether a speaker was being truthful or lying about the location of a prize in a computer game. These utterances were made in a fluent or disfluent manner. Results show that judges' eye and mouse movements tend to be directed towards the location mentioned by the fluent speaker. On the contrary, with the disfluent utterances, the opposite bias happened in that the focus of attention was directed to another location. These results point towards the fact that disfluencies can influence the listener's assessment of whether one is being truthful or lying about his or her own statements. The link between disfluencies and deceptive behavior has been often argued to be a result of the fact that telling a lie raises the cognitive load of the lie teller, and therefore more disfluencies are produced, and/or by the emotional arousal that telling a lie might provoke as a consequence of the experienced feelings and emotions, such as excitement, nervousness and guilt (Vrij & Winkel, 1991).

Additionally, the role of pauses in deceptive speech has also been studied (Benus et al., 2006; Fox Tree, 2002; Hirschberg et al., 2005), however, results do not seem to be consistent. On the one hand, some studies have shown an association between filled pauses and deceptive speech (Fox Tree, 2002; Vrij, Edward, Roberts, & Bull, 2000). Other studies show that different types of pauses – silent and filled pauses – correlate significantly more with truthful speech (Arciuli, Mallard, & Villar, 2010; Benus et al., 2006; Hirschberg et al., 2005). For instance, the study from Arciuli et al., (2010) investigated the use and acoustic nature of "um" and "like" in elicited lie-telling versus truth-telling. Results show that "um" occurred less frequently, and it was also shorter in duration during the lie tells than in truthful utterances. According to the study, a possible explanation for this is that "um" might play a role much more similar to interjections, which contribute to a more natural and authentic communication style, which seems to be lacking in deceptive speech. Similarly, another study also showed that the use of silent and vocalized pauses is linked more with truthful speech rather than lies. Likewise, the explanation given points to the idea that deceptive speech is more planned and less spontaneous than truthful speech (Benus et al., 2006). These results conflict with the idea that pauses' rate is higher in deceptive speech because of the higher levels of cognitive load and arousal that have been commonly associated with lying behavior. On the contrary, these results seem to indicate that deceptive speech might be more cautiously planned.

It is worthwhile to study pausal behavior in children's speech as well, and their potential role as cues to deception, as it has been shown that the use of filled pauses is age-related, i.e., their relative frequency increases with age (Esposito et al., 2004; Narayanan & Potamianos, 2002), and may serve a different functional role in children's and adult speech (Krahmer & Swerts, 2005). For instance, a previous study shows that a clear cue for adult's uncertainty are the use of fillers, whereas in children speech the fillers have no clear relation with the expression of uncertainty (Krahmer & Swerts, 2005).

In sum, there is some research on deceptive speech, most of which focuses on lies by adult speakers, with results that are not always consistent between studies. It would be fruitful to explore these phenomena in children as well since it is conceivable that children signal deception differently from adults, especially in their use of specific auditory features. Therefore, the present study aims to further explore disfluencies and acoustic measures in children's speech, as possible cues for deception detection.

Method

Lie elicitation Paradigm

The present study builds on a dataset that was gathered with a previously designed paradigm (*"Guess what I have behind the back?"*)(Serras Pereira et al., 2016). The paradigm - *"Guess what I have behind the back?"* was inspired by previous work (Talwar & Lee, 2002a, 2002b; Talwar & Crossman, 2011) and it was designed as an attempt to naturally prompt truthful and deceptive statements from children in a game context. In this game, an adult (experimenter) had to guess the object (specifically, a fruit or animal) that was hidden behind the child's back, by asking 9 simple questions, such as "Is it a fruit or animal? What is the size? etc.". In the end, the experimenter had to try to guess the object. This game was played in 3 conditions – Truthful (Tc), Lying 1 (Ly1) and lying 2 (Ly2). In the truthful condition, the children replied to the questions in an honest manner. For the lying conditions, a confederate elicited the children to lie (to the experimenter), by giving incorrect answers about the object hidden behind their back. If this was accomplished, the children would win the game and get a reward. To elicit the lies, first the experimenter left the room with an excuse (to pick up a phone call, or to pick up the next child that would play the game), and next the confederate used the argument that the experimenter was saying out loud to everyone that she was the best in this game. As mentioned before, the game was played twice in the lying condition (Ly1 and Ly2), in which the main difference was related to the fact that on the Ly1 the experimenter guessed the object wrongly, and therefore lost the game; however, on the Ly2 the experimenter guessed the corrected object despite the description that the child gave, and therefore won the game. The existence of variants on the lying condition was motivated by previous results (Swerts et al., 2013), in which children's second attempts to lie showed more nonverbal cues.

This earlier study focused on nonverbal correlates of deception in children's body movement. In the study, clips from truthful and deceptive children were shown to adult judges, who were given the task to decide whether the children were being truthful or not. Results show first that this paradigm naturally elicit lies among children in a game context. Furthermore, results also reveal that judges were able to accurately distinguish truthful clips from lying clips based on the nonverbal behavior of the children. Finally, an automated movement analysis which basically measures the extent to which a child moves different body parts shows a positive correlation between the amount of movement in a child and the perception of lies (from the judges), i.e., the more movement the children exhibited during a clip, the higher the chance that the clip was perceived as a lie (Serras Pereira et al., 2016).

Participants

The dataset consisted of 42 Portuguese children between 6 and 7(M=6.38) years old, from the 1st year of primary school. Prior to the experiments, signed consent forms from the children's parents were collected, in which permission was asked for each child to participate and to be recorded. It was also stated that the data and recordings of the children would be treated with confidentiality, and that they would only be used for scientific purposes.

Procedure

The games lasted on average between 20-30 minutes, depending on the pace of the child, and involved 5 phases. In the introductory stage, the briefing, the experimenter explained the game to the children. During the warming-up phase, a practice game was played, in which the experimenter hid the object behind her back, and the child had to try to guess what it was by asking some questions. The 3rd and 4th phase consisted of the real experiment. The difference between the warming up and the actual experiment was that the experimenter and the participating child switched roles, as it was now the experimenter's turn to guess the object that was hidden behind the child. First, the game was played in the truthful condition, and then it was played on both lying conditions. Finally, the game ended with a short debriefing, in which the reward was given to the children. More details about the experimental procedure can be found in Serras Pereira et al., 2016 (chapter 2).

Materials

All the games were recorded using a Sony HD video camera, which also captured their voices. All the children were standing upright in front of the camera, not only to guarantee that the distance to the microphone would be more or less equal for all the children, but also to assure that full-body motion was captured.

Stimuli

The audio from the 42 children from each of the 3 conditions was extracted from the movie clips. Two different types of utterances – long open utterances and minimal pairs were selected for different type of analysis. For the manual and global analysis, the children's answers to the open question *"Can you give me more cues about that object?"* were selected for that purpose. Out of the 42 children, 8 children were not considered because either the answer was not sufficiently intelligible, or because they did not lie in both lying conditions. This resulted in a total of 102 adequate speech utterances from 34 children in the three conditions (Tc, Ly1 and Ly2). For the automatic acoustic analysis, minimal pairs of words from 26 children in the three conditions were selected. In total, 78 small utterances to the question *"is it a fruit or animal?"* in which the answer could only be either *"fruit*" or *"animal"* were taken into consideration. Finally, 8 children from a total of 34 (in the 3 conditions) were also removed for the automatic acoustic analysis, mostly because the signal-to-noise ratio was too disturbing for audio analyses.

Results

Manual Analysis

In order to explore the presence and absence of different type of speech disfluencies, such as Long Pauses (LP), Filled Pauses (FP), Prolonged Words (PLW) (e.g. "it's a doooog") Hesitations (H) ("it's, it's, it's a dog!"), the data were manually annotated, in terms of whether or not such a phenomenon was present or not. To this end, the children's answers to the question "Can you give me more cues about that object?" were selected for the analysis (rather than the yes/no questions in the paradigm which generated relatively short responses). Indeed, the open question elicited longer responses, and were expected to lead to more disfluencies as children were required to elaborate on their response. For this analysis, 102 good speech utterances from 34 children in the three conditions (Tc, Ly1 and Ly2) were considered.

Next, a Chi-Square analysis was performed to understand the relation between the presence/absence of long pauses (LP), filled pauses (FP), prolonged words (PLW), hesitations (H) and tempo in the three conditions (Tc, Ly1 and Ly2). As presented in tables 1 and 2, results show that regarding the presence and absence of LP and FP there is a significant difference between the three conditions (LP: χ^2 (2,102) = 8.08, *p<.02;* FP: χ^2 (2,102) = 8.13, *p<.02)*, as both types of pauses are less likely to occur in the lying conditions (Ly1 and Ly2) compared to the truthful condition.

Table 1: Cross tabulation of Long Pauses in the three conditions

Condition	Long Pauses	
	Absence	**Presence**
Truthful	13	21
Ly1	15	19
Ly2	24	10

***p ≤ .05*

Table 2: Cross tabulation of Filled Pauses in the three conditions

Condition	Filled Pauses	
	Absence	**Presence**
Truthful	14	20
Ly1	16	18
Ly2	25	9

***p ≤ .05*

In order to further understand this phenomenon, we also explored for both type of pauses where they had occurred in the utterances, so that we specified two subcategories: Start= in the beginning of the speech or In= during the speech. A Chi-Square analysis revealed that for the

LP_Start and LP_In cases there is no statistical significance between truthful and deceptive conditions, whereas the LP_In approaches significance (LP_In: χ^2 (2,102) = 5.38, *p= .068*). And in both cases, the trend of less occurrences in the lying conditions prevailed, since the analysis revealed less LP occurrences in the beginning of the speech (Percentage of LP_Start on: Tc= 42.9%, Ly1= 35.7% and Ly2= 21.4%) and in the course of the speech (Percentage of LP_In on: Tc= 43.3%, Ly1= 40% and Ly2= 16.7%) during the lying conditions.

A similar analysis was conducted for the FP that occurred either in the beginning or during the speech. As revealed in table 3, results show that for the LP_Start there is a significant difference between the conditions (χ^2 (2,102) = 10.482, *p= .005*) with less occurrences of these FPs in the lying conditions. Yet, no significant differences were found for the LP_In cases, even when here again there were fewer FPs that occurred during the utterance in the lying conditions than in the truthful condition.

Table 3: Cross tabulation of Filled Pauses in the beginning of the speech in the three conditions

	Filled Pauses_Start	
Condition	**Absence**	**Presence**
Truthful	18	16
Ly1	21	13
Ly2	20	4

***p ≤ .005*

Regarding the presence or absence of prolonged words (PLW), the Chi-Square analysis depicted in table 4 shows that PLWs significantly more often occurred in the lying conditions than the truthful conditionχ^2 (2,102) = 6.918, *p= .031*).

Finally, concerning the manually determined speech tempo and the speech hesitations, the Chi-Square analysis revealed no statistical difference between the three conditions (Tc, Ly1 and Ly2).

Table 4: Cross tabulation of Prolonged Words in the three conditions

Condition	Prolonged Words	
	Absence	**Presence**
Truthful	33	1
Ly1	26	8
Ly2	26	8

$*p \leq .05$

Automatic Acoustic Analysis

In addition to the manually annotated data, we also performed a number of acoustic analyses, based on automated measures of a number of prosodic features. To this end, we ran a Praat script on 78 small, specifically selected utterances (during which 26 children either said "*fruta"* or *"animal"*), that were responses to the question "is it a fruit or animal?" in the three conditions (Tc, Ly1 and Ly2). These utterances were specifically selected because they were lexically similar across the three conditions, which facilitated the acoustic comparisons. The measures that were used (in the script) for the analysis were: duration, pitch, intensity, jitter and shimmer. In addition, two more measures –length of the word (the time that children take to pronounce the word *"fruta"* or "*animal"*) and delay (the time that children take before saying the word *"fruta" or animal")* - were also manually annotated, and further analyzed. Table 5 gives an overview of these acoustic measures, and respective units of measure.

The reason for doing this acoustic analysis was related to the fact that some studies have associated these features, such as pitch and intonation, with deception detection on adults (Benus et al., 2006; Bond & Depaulo, 2006; Ekman et al., 1991). Accordingly, these features should also be explored and tested in children, since it is conceivable that children signal deception differently from adults. Therefore, through a Repeated Measures Anova, we tested whether the three experimental conditions (Tc, Ly1, Ly2) differed with respect to these different acoustic measures (duration, pitch, intensity, jitter, shimmer, delay and length). Table 6 shows all the significant effects found regarding the acoustic measures mentioned above

For the intensity measure, the automatic analysis evaluated it in different respects such as the variation in terms of means (Int_Mn) and standard deviations (Int_SD), the minimum (Int_Min) and maximum (Int_Max) levels, the intensity at .05 (Int_.05) and 0.95 (Int_.95), and at levels below 500 Hz (Int<500) and below 1000 Hz (Int_<1k). Results from the Repeated Measures Anova showed a statistical significant effect of condition in terms of Int_Mn (intensity mean) ($F(2, 50) = 8.929$, *$p<.001$)*. Post Hoc comparisons using the Bonferroni correction indicated that both lying conditions (Ly1: M= 65.77, SD=4.21; and Ly2: M= 66.31, SD=5.31) are significantly different and have a higher measurement of Int_Mn than the truthful condition (M= 62.98, SD=3.50), but no statistical significance was found between the two lying conditions (Ly1 vs. Ly2). Regarding the Int_Max (intensity maximum), a significant effect of condition was also found ($F(2,50)=5.431$, *$p<.05$*). Similarly, the Post hoc Bonferroni corrected comparisons revealed a statistical difference between the Ly2 (M= 74.40, SD= 4.73) and the Tc (M= 71.29, SD= 4.18) conditions, whereas the difference between Ly1 (M= 73.57, SD= 4.76) and Tc was not significant.

Table 5: Overview of the acoustic measures used for the automatic analysis

Feature	Acoustic measure	Unit
Loudness	Magnitude of the sound wave	Db
Pitch	Fundamental frequency (F0)	Hz
Jitter	Deviation from true periodicity	Hz
Shimmer	Variability in peak-to-peak amplitude	Db
Utterance duration	Length of the total turn that children need to respond	Ms
Length of the word	Time children need to pronounce the word *"fruta"* or "*animal"*	Ms
Delay	The interval between the end of the question and the onset of the child's response	Ms

For the intensity 0.95, results followed the same trend, showing an effect of condition ($F(2,50)= 5.075$, $p<.05$), in which the Bonferroni correction method revealed a statistical difference between the Ly2 (M= 72.52, SD=5.02) and the Tc conditions (M= 69.77, SD= 4.21), but no statistical difference between Ly1(M= 71.94, SD= 4.45) and Tc. These results showed once again higher values of Int_.95 in both lying conditions. Moreover, the statistical analysis established a statistical effect of condition for the Int<500 (intensity below 500Hz) ($F(2,50)= 7.07$, $p<.002$) and for the Int<1k (intensity below 1000Hz ($F(2,50)= 8.13$, $p<.001$). Regarding the pairwise comparisons of the conditions, the Bonferroni analysis showed a statistical difference between the Ly2 (Int<500: M= 64.84, SD=4.96; Int<1000: M=66.04, SD=5.29) and the Tc (Int< 500: M= 61.58, SD= 3.47; Int<1000: M=62.77, SD= 3.53) conditions, but only a statistical difference for Int<1k between the Ly1 (M=65.41, SD=4.19) and Tc. No statistical differences were found for the comparison between the Ly1 and Tc on intensity<500. Furthermore, no significant differences were found for Int_Min and Int _05.

In addition, results revealed a significant effect of condition for jitter local ($F(2,50)= 4.79$, $p<.01$), in which only significant difference between the Tc (M= .04, SD=.01) and the Ly2 was found (M= .03, SD=.008), but no significant difference when comparing these with the Ly1 (M=.034, SD=.014).

Finally, no significant differences were found for duration, pitch, shimmer, delay and length across the three conditions.

Table 6: Repeated Measures Anova effects for Intensity and Jitter measures

Acoustic Measures	Condition			
	Truthful	Ly1	Ly2	
Intensity	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	***F stats***
Int_Mn	62.98 (3.50)	65.77(4.21)	66.31(5.31)	F (2, 50)=8.92, *p<.001*
Int_Max	71.29 (4.18)	73.57 (4.76)	74.40 (4.73)	F (2,50 =5.43, *p<.05*
Int_.95	69.77 (4.21)	71.94 (4.45)	72.52 (5.02)	F(2,50)= 5.07, *p<.05*
Int<500	61.58 (3.47)	63.84(4.14)	64.84 (4.96)	F(2,50)= 7.07, *p<.002*
Int<1000	62.77 (3.53)	65.41 (4.19)	66.04(5.29)	F(2,50)= 8.13, *p<.001*
Jitter_Loc	.040 (.011)	.034 (.014)	.031 (.008)	F (2,50)= 4.79, *p<.01*

Discussion

The present study was an attempt to understand the acoustic properties of children's speech in truthful and deceptive interactions. To achieve this, a lie elicitation game called "Guess what I have behind the back?" was used, which was inspired by the temptation resistance paradigm used in previous work (Talwar & Lee, 2002a, 2002b; Talwar & Crossman, 2011). In the present study, children were given the opportunity to lie about an object hidden behind their back to win a game, and get a prize. Long and small speech utterances of children in deceptive and truthful interactions were analyzed in terms of acoustic properties, which led to several new and interesting findings.

First of all, results revealed that LP (Long Pauses) and FP (Filled Pauses) are less frequent when children are producing deceptive speech, which goes in line with previous findings (Arciuli et al., 2010; Benus et al., 2006; Hirschberg et al., 2005) that showed that these type of pauses in adults' speech were more correlated with truthful speech than deceptive speech, and do not corroborate previous studies (Fox Tree, 2002; Vrij et al., 2000) that found more disfluencies in deceptive speech. It can be argued that like adults (Arciuli et al., 2010; Benus et al., 2006; Hirschberg et al., 2005), children between 6-7 years old are also able to carefully plan their deceptive speech, and as a consequence of this preprocessing, less pauses are made during a lie tell. Moreover, when differentiating these pauses in terms of where in a speaking turn they had occurred (beginning and/or in the middle of the speech), the general outcome remains true, i.e., less occurrences of pauses in deceptive speech compared with truthful speech. This result is also very interesting because it not only suggests that children are planning their deceptive speech, but it also reflects that children at this age are already making an effort to keep their deceptive speech consistent throughout the entire lie, and therefore showing a consistent pause pattern in their speech (i.e. less pauses irrespective of their position in the utterance). In fact, this supports the idea that around 6-7 years old children are already making an effort to maintain semantic control in their lies, and taking into account the other (to whom they lie), as an attempt to not reveal noticeable signs of stress or nervousness, and therefore reduce the risk of being caught during the lie-tell

(Talwar et al., 2007; Talwar & Lee, 2002a). This is a consequence of children's ToM at this age, in the sense that it reflects that children are aware that such signs might be interpreted as cues to deception by the others, and therefore they avoid them even more than in truthful speech.

Interestingly, PLW (Prolonged Word) showed an opposite pattern, as these were more frequent in children's deceptive speech than in truthful interactions. At the moment, we are not clear as to what could explain this pattern: on the one hand, it can be argued that the presence of more PLWs in children's deceptive speech is the result of a compensation mechanism, i.e. an attempt to cover the less frequent use of pauses, and to sound more natural, and less acted in their deceptive performance. On the other hand, this PLW can be considered (semantic) leakage, in the sense that having the necessity to describe the objects with verbal exaggerations (e.g. "It's biiiiig!") might be a consequence of cognitive overload, and in this way children are also able to gain time to build up the sequence/storyline of the lie. In other words, this means, that PLW can be a signal of cognitive overload, in the sense that creating and telling a lie is cognitively very demanding. As a consequence of this demand, children have a tendency to use more prolonged words during their lie tell, which probably also contributes to gain more time to elaborate mentally the next lines of the lie.

Lastly, the automatic analysis showed also noteworthy findings, given that children's deceptive speech has higher values regarding different levels of intensity but also less jitter variation when compared to truthful discourse, which is partly in line with a previous study that associated deceptive with higher range of intensity (Rockwell et al., 1997). Deceptive speech with higher intensity levels with less jitter variation probably reflects also an attempt to sound as truthful, clear and natural as possible (and avoid being caught as a lie teller). However, most of these differences were more clearly visible between the truthful condition and the second lying condition, which goes in line with previous findings (Serras Pereira et al., 2016). In this study, children leaked more bodily cues during their second attempt to lie compared to the first attempt of lying, which was explained by the ironic effect of lying, i.e. the child's awareness of the fact that it is producing a (second) lie leads to the ironic fact that it becomes harder to hide nonverbal cues to deception (Serras Pereira et al., 2016). Therefore, it can be argued that a similar process happens in some of the acoustic correlates of speech we measured. The ironic effect of lying is also observable in the second attempt of deceptive speech, i.e. by having the awareness of their second attempt of lying, children tend to overcompensate the levels of intensity and (less) jitter variation (possible because of an attempt to sound natural), but in reality, these can be considered acoustic leakage, as they may be the result of an effort to sound even more natural than when saying the truth.

In sum, results seem to reflect that during their deceptive interactions, children attempt to sound as truthful and natural as possible, which is explained not only by the higher levels of intensity and less jitter variation in their deceptive interactions, but also by the smaller amount of pauses used in the (deceptive) speech, as a reflection of a more carefully planned speech. However, the use of more prolonged words in their deceptive speech seems a bit inconsistent with these patterns. As mentioned before, it can have two possible explanations, i.e. it can be related to a compensation effect or considered to be leakage.

Conclusion

To summarize, the results of this study showed that children partly behave like adults in their deceptive discourse, in particular regarding the presence of LP and FP. But, it also showed that there are significant differences with respect to certain acoustic measures between truthful and deceptive speech, such as less jitter variation and higher intensity levels during lie-tells. These results can partially be explained by the so-called ironic effect of lying. Finally, this phenomenon of reducing the use of pauses and overcompensate certain acoustic measures, is probably an attempt to (re) achieve speech stability, and sound like natural and truthful speech.

In conclusion, the present study revealed interesting and new findings, but further research needs to be performed. In the future, a more detailed analysis regarding the relation between semantic leakage and certain types of disfluencies, in particular fillers and prolonged words, should be explored. Furthermore, some content analysis in longer utterances of deceptive speech might reveal additional information. To achieve this, the experiments should ideally be designed to get lexically similar and longer utterances across different conditions.

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4

Children's lying behavior in interactions with personified robots

Abstract

This study investigates how young children between 4 - 6 years old interact with personified robots during a lying situation. To achieve this, a temptation resistance paradigm was used, in which children were instructed to not look at a toy (behind their back) while the instructor (a robot dog, a humanoid or a human) left the room. Results revealed that regardless of the type of communication partner, children's peeking behavior was similar across the 3 conditions, while there was a tendency of lying more towards the robots. The majority of the children (98%) showed semantic leakage while telling a lie, and most of them (89%) lied and denied their peeking behavior. Additionally, children generally gave more verbal responses to the robot dog and to the humanoid in comparison with the interaction with the human. Furthermore, the mean pitch of children differed between the robot conditions, i.e. the mean pitch was significantly lower in the robot dog condition in comparison with the humanoid condition. Finally, facial expression analysis showed that children generally appeared happier when they were interacting to the robot dog compared to the humanoid or human.

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Introduction

Child-robot interaction is an emerging research field, which recently has yielded a significant amount of studies, ranging from supporting teaching and educational activities through robotic applications (Tanaka et al., 2007; Draper & Clayton, 1992) to helping autistic children in training their social skills using social robots (Stanton et al., 2008). In general, robots in this area of research are explicitly designed to build relationships with humans, and to bring an added value to children's life. Accordingly, social robots are becoming more adaptive, personified, embodied and autonomous (Breazeal, 2003) and have been shown to strongly influence the way children perceive the world (Kahn et al., 2004; Severson & Carlson, 2010; Turkle, 1999).

However, while there may be many benefits of having robots with which one can build close relationships, social robots could also be misused as well. Particularly, social robots can be deceptive towards people, and this artificial deceptiveness can lead to various threats. For instance, people may assume that the confidential information they passed to a robot, remains confidential, but in reality social robots may pass these sensitive and secret details unnoticed to a third party (Westlund & Breazeal, 2015). Therefore, artificial deceptiveness can cause serious security breaches in specific contexts (Coeckelbergh, 2012). Child-robot interaction is one of those areas where this artificial deceptiveness could prove to be particularly vulnerable (Westlund & Breazeal, 2015). The impact that robots might have in children's life raises questions and concerns about trust and privacy, in particular because according to previous studies children tend to treat robots as friends and companions (Kanda et al., 2004; Kahn et al., 2012).

Since artificial deceptiveness could potentially affect the future use and acceptance of robots by children in everyday life, it is important to understand this phenomenon by conducting more research on how children behave towards robots in deceptive contexts. Because social robots could be deceptive towards children, it is important to investigate to what extent children view different types of robots as trustworthy partners, and how this compares to their interactions with human beings. One intriguing questions in this respect is related to the degree to which the children's Theory of Mind (ToM), i.e., the ability to attribute mental states to another partner and recognize differences between one's own and the other's perspective, varies as a function of the type of communication partner. Previous research has proven that in order to produce a successful lie, children need, first of all, to understand their own mental state as well as the mental state of the person to who they are lying (first order belief), and also to keep semantic control over the entire lie (second order belief) (Talwar et al., 2007). Additionally, it is known that children leak some verbal and nonverbal cues while telling a lie despite the fact that previous studies showed inconsistent results regarding which cues are the most relevant and reliable for lie detection (Feldman et al., 1979; Lewis et al.,1989; McCarthy & Lee 2009; Talwar & Lee, 2002a ;Vrij et al., 2004). Therefore, it is relevant to explore if children exhibit similar verbal and nonverbal cues while lying to robots, as the ones that they show during human interaction.

In addition, as social robots for children are coming in different forms, with movements, shapes and behaviors that could be artificial or more human-like, it is relevant to explore if children's deceptive behavior is affected by such variability in the robot's appearance. In sum, the present study aims to gain understanding of children's lying behavior towards robots, not only to improve child-robot interaction, but also to shed light on human deceptive skills in various contexts.

Children's Lying behavior

Children's ability to lie appears as early as 2.5 and 3 years, and tends to improve with age (Lewis et al., 1989; Newton et al. 2000) According to previous studies, learning to lie is an essential step and part of a normative behavior in children's development (Talwar & Crossman, 2012; Talwar & Crossman, 2011). Around 3 years-old, children have already some conceptual understanding of lying behavior (Siegal & Peterson,1998; Talwar & Lee, 2002b), probably because in early stages of their life, parents and caregivers taught children the negative moral implications associated with telling a lie (Xu et al., 2010).

Previous work suggests that there are two main types of lie that occur during children's socialization (Xu et al., 2010). The first type consists of so-called antisocial lies. These lies tend to violate moral rules, and are told for self-serving purposes. These are usually the first type of lies that children are able to produce (Lewis et al. 1989; Talwar & Lee, 2002a). The second type consists of prosocial lies (white lies), and these are told with the intention to benefit or help another person, and/or for politeness purposes. Studies about white-lies have shown that children between 3-7 years old are able to produce a white-lie for the benefit of the other (Talwar & Lee, 2002a), and for politeness purposes (Talwar et al., 2007).

In order to produce a consistent lie, children not only need to be able to control their nonverbal behavior, but also need to avoid what is called semantic leakage. This means that children need to maintain consistency between their initial false statements and follow-up statements in order to produce a reliable lie (Talwar & Lee, 2002a), their nonverbal behavior should appear as natural comparable to what they show in truthful situations, and not reveal obvious signs of stress, guilt or nervousness. Findings from previous studies regarding such issues of children's nonverbal behavior during a lie-tell are fairly inconsistent. Some studies have linked more positive nonverbal cues with deception, such as smiles, confident facial expressions and a more positive tone of voice (Feldman et al., 1979; Lewis et al., 1989). Other studies have shown that children have less control over their nonverbal expression while producing a lie (McCarthy & Lee, 2009; Vrij et al., 2004).

Regarding verbal cues on children's deceptive speech, studies brought to light that young children are not the most skillful liars (Talwar & Lee, 2002a;). The findings suggest that between 3-5 years old, children cannot keep their deceptive discourse semantically coherent and consistent with an initial lie. But between 6-7 years old, half of them are able to keep a certain level of semantic leakage control, and consequently diminish the risk of being caught by others.

In sum, the previous findings are quite inconsistent regarding nonverbal and verbal cues that children might leak while telling a lie. Therefore, it is relevant to explore if these possible cues are also shown when children lie and interact with different robots; and if children exhibit similar ToM towards robots, i.e., whether children "beliefs" about a robot's mental state, and how these compare to their beliefs about human communication partners.

Lie detection methods

Past research on deception in general has shown that the automatic or human detection of lies is a very demanding task, with accuracy levels usually around chancel level (Bond & Depaulo, 2006; Edelstein et al., 2006). A meta review of 125 studies about deception revealed that there is not a single unique verbal, nonverbal or physiological cue related to deception (Vrij, 2004). However, several techniques have been used for lie detection, from human judges that operate as lie detectors to more novel and automated measures, due to the advancement in Social Signal Processing (SSP) For instance, eye tracking technology has been used to distinguish liar's gaze patterns from truth-tellers (Wang et al., 2010). Automated movement analysis has started to be used for the same purpose (Serras Pereira et al., 2014; Eapen et al., 2010; Duran et al., 2013), as well as physiological data, such as galvanic skin conductance (Van't Veer et al., 2014), and brain activity (Ding et al., 2013; Kozel et al., 2005). However, despite the variety of tools used for detection, there is not yet a clear and systematic way to achieve highly accurate lie detection results. These methods require not only a considerable amount of experimentation, and lie detection methods that rely on only a limited set of features fail to produce good results, since as described above there is a range of possible cues to deception, from verbal to nonverbal signals. Hence, the present study uses multi-method approach for analyzing children's interaction and lying behavior during human-human and human-robot communication.

Children's beliefs about robots

It is clear that children are quite susceptible to robots, and often tend to treat robots as friends (Kanda et al., 2004; Kahn et al., 2012). Robots can easily gain the trust of young children. It has been argued that, compared to what they do with their puppets, children feel more inclined to share their secrets with humanoid robots (Bethel et al., 2011); as a matter of fact, the use of puppets as a technique to help children sharing their 'secrets' has been shown not to be very efficient or successful (Carter & Mason, 1998; Johnston, 1997). In the study from Bethel et al. (2011), children between 4-6 years old were asked to keep a secret, and later on were prompted either by a humanoid (NAO robot) or a human to tell that secret. Qualitative results indicated that children were as likely to share the secret with the robot as the adult (with a similar amount of prompting effort). Moreover, these children interacted with the humanoid using similar social conventions as observed in their interactions with the adult, such as greeting, turn taking, etc. This finding is interesting in view of the assumption that there might be a disconnection between what children know about the functioning of robots and what they think about robots as entities (Westlund & Breazeal, 2015). For instance, around 4 years children barely attribute any biological property to robots despite the fact that they still attribute some psychological capacities, such as emotions and cognition (Jipson & Gelman, 2007). Children around 5 year-old believed that robots do not have a brain, however children between 7-11 years old assumed that robots have a certain type of brain that is different from the human version (Scaife & van Duuren, 1995). In addition, children who have had experience with robots tend to attribute intelligence features to a robot, instead of aliveness features (Bernstein & Crowley, 2008). Moreover, according to these children this level of intelligence is different and distinct from human or animal intelligence. Similarly, the results also showed that children with (almost) no experience with robots, not only attributed aliveness features, but also emotional and intellectual abilities to robots.

Thus, past work has shown that children have a tendency to attribute some of the human abilities to robots. However, this attitude towards robots may depend on the kind of robot they are interacting with, which may look very humanoid or more artificial in nature (such as robot dogs). In a study that compared children's interactions with a robot dog and a (real) dog, it became clear that children (aged between 7-15 years old) showed closer proximity and more touching with the real dog. However most of the children also treated the robot dog in ways very similar to the interaction with the real dog. Surprisingly, children also attributed mental states (56%), social skills (70%) and moral standing (76%) to the robot dog (Melson et al. 2005). Similarly, in a study that focused on children's reasoning and interactive behavior towards a robot dog (AIBO robot), 66% of the children accorded mental states, social rapport and moral standings to the robot dog. Furthermore, 50% of the children attributed biological properties and 25% also attributed some animacy properties to the robot dog (Kahn et al., 2006). Likewise, in a different study, children have shown to speak similarly to a real dog and to a robot dog. Most of the children gave commands as frequently to the robot dog as to the real dog. Furthermore, children used body movement and objects such as balls to elicit play with the robot dog (Melson et al., 2009). In other words, we have gained insight into the way children interact with and feel about different types of robots. To explore this further and see to what extent children view robots as trustworthy partners, the current study will look into children's lying behavior. As discussed above, lying has been argued to be related to children's ToM, and their beliefs about the other's mental states. Little is known about children's deceptive skills towards different types of robots. It might be the case that children's lying behavior towards robots diverges significantly from how they lie to a human. In addition, their behavioral patterns in deceptive situations may vary as a function of the type of robot: maybe, telling a lie to a humanoid turns out to be similar to a human because humanoids are closer in shape, and children tend to attribute some of the human aspects to these types of robots. On the other hand, telling a lie to a robot dog might be different, as they are viewed more as pets, such as real dogs, and are more fun and relaxing to play with. Therefore, we will explore deceptive behavior in children's behavior using a variant of a well-attested paradigm, and compare interactions of these children with humans, humanoids or robot dogs, and see whether these reveal differences in relative amount of lies, and specific verbal, auditory and nonverbal correlates.

Data Collection

Lie Elicitation Paradigm

Several different paradigms have been used to investigate children's lying behavior. In particular, some studies have used a modified version of the temptation resistance paradigm (Lewis et al., 1989; Talwar et al., 2007; Talwar & Lee, 2002b; Talwar & Lee, 2002a). In this type of paradigm, children are given the opportunity to spontaneously lie due to the opportunity to commit a transgression. According to a previous study, in which children had the opportunity to peek at a game's answer and lie about it, half of the children between 6 and 11 years old did not resist the temptation and peeked at the answer (Talwar et al., 2007). Additionally, another study has shown that this paradigm works with children around 4 and 5 years, and moreover some of these children lied over their peeking behavior (Lee, 2013).

Based on this, the present study used a temptation resistance paradigm in a guessing game to elicit deceptive behavior among children. The guessing game was played in 3 conditions – human condition, humanoid condition and robot dog condition. The reason for having two different personified robots, specifically a humanoid and a robot dog is based on what was above described in the literature studies about personified robots (Bethel et al., 2011; Kahn et al., 2006; Melson et al., 2009). In short, the reason for having a humanoid robot is because it resembles, and it is closer in shape to humans. Regarding the robot dog, it is clear that children easily engage with them, and behave towards them in a more playful way as they do with real dogs.

The sequence of events was very similar across the three conditions. However, in the robot conditions the lie elicitation and the guessing game were conducted either by the robot dog or the humanoid (instead of the human experimenter). Below the control condition is explained in full detail.

It was told to each child that they would play a game, in which the child had to try to guess the toy that was placed behind his/her back. To achieve this, the child was seated in a chair and was told to not look at the toy (initially covered with a blanket) that was placed on a table behind his/her back. Before leaving the room, with the excuse that he (the experimenter) forgot a pen, the experimenter removed the blanket, and emphasized once again that while he was away, the child should not look at the toy. Additionally, the experimenter mentioned that after his returning, they would play the guessing game, and the child could get a prize if the toy was guessed correctly.

Subsequently, the experimenter left the room, and was absent for around five minutes. During this time, the child was alone in the room. After this, the experimenter re-entered the room and said that he hoped that the child did not look at the toy. Then, the experimenter initiated the guessing game that consisted of 6 questions related to the object. The questions were as follows: 1. *"Did you peek at the toy?"; 2. "Which color do you think the toy has?"; 3. "How does the toy look like?"; 4. "The toy is an animal. Which animal is it?"; 5. "Can you describe how the animal looks like?"; 6. "Which sound do you think the animal makes?".* After asking the questions, the experimenter told the child the game was over and that he could look at the toy. In all cases, the child received a sticker as a reward.

Regarding the robot conditions, the only difference was the robot shape (appearance) - in one condition, it was a Lego Mindstorms EV3 humanoid whereas on the other one it was Lego Mindstorms EV3 robot dog (Figure 1).

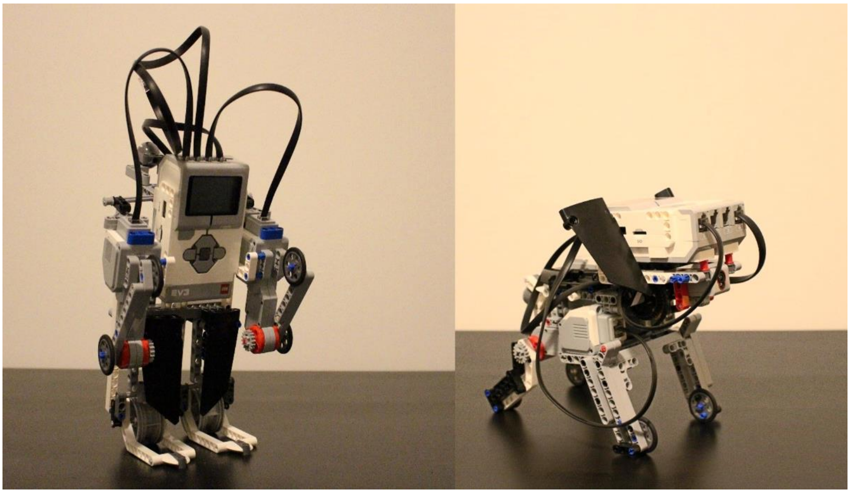

Figure 1: The Lego Mindstorms EV3 humanoid (left) and the Lego Mindstorms robot dog (right).

In both robot conditions before the child entered the room, the human assistant asked each child to interact and play the game with the robot. First of all, when the child entered the room, the robot (humanoid or dog) asked the child to sit down on the chair. Further, it told the child that the human assistant would uncover the toy. The robot emphasized that the child should not look at the toy. While the robot was sitting down (and the human assistant was leaving the room), the robot said that its batteries were almost empty, and they needed to be replaced. The human assistant came again and took the robot out of the room. Before leaving, the robot emphasized again that the child should not look at the toy. Like in the control condition, the robot was absent for around five minutes. During this time, the child was alone in the room. When the robot re-entered the room, the game and questions were asked exactly like in the control condition (by the humanoid or robot dog). Additionally, for all robotic statements, a female human voice was used to ensure the robot conditions differ from the human assistant.

Participants

Eighty-five children from an elementary Dutch school participated (52 boys, 33 girls; mean age = 4.58 years, SD = .60). There were 27 children in the human condition, 28 in the robot dog condition and 30 in the humanoid condition.

Experimental setup and materials

The children had to sit in front of a table in a room with their back to a second table, where the toy was placed. The toy was a rubber duck (height ≈ 24 centimeters, width≈ 20 centimeters), which was initially and prior to the experiment covered with a blanket. The table in front of the child had a hidden compact camera (Sony NEX-5N), next to another camera (Canon 500D) and two camera bags. During the experiments, the hidden camera (Sony NEX-5N) was making audio and video recordings (Figure 2).

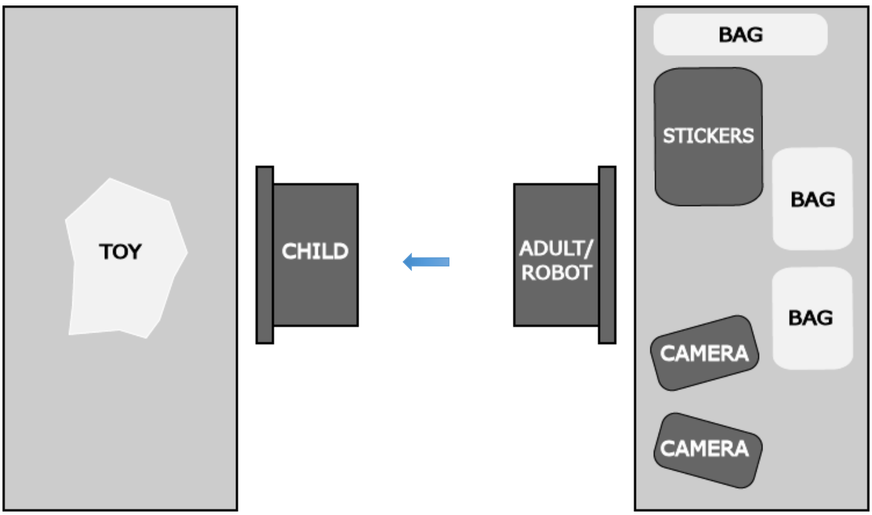

Figure 2: Experimental setup for the three conditions. The arrow in the figure points to the hidden camera.

Procedure

The children were randomly divided in three conditions: the human condition (i.e. the control condition), the robot dog condition and the humanoid condition. The children were told they were going to play a guess game with a hidden toy and they could win a prize if they could guess the correct toy (Figure 3). The experiments were individually paced, and last approximately 10 minutes.

Figure 3: A child playing the game in the humanoid condition.

Results

The following behaviors - peeking behavior, verbal behavior, semantic leakage and nonverbal responses were taken into account for the analysis. The presence or absence of these behaviors was individually coded for each child.

Peeking behavior analysis

Regarding peeking behavior – if children peek at the toy when the experimenter/robots were absent from the room – out of the 85 children that participated, 50 children (59%) were curious during the experiments and showed a clear backward glance. This peeking behavior – looking at the toy in the absence of the experimenter/robots – was confirmed in the video recordings by the experimenter at a later stage. Furthermore, 63%of the children in the human condition (N=27) peeked at the toy, whereas in the humanoid condition (N = 30) a percentage of 67% looked at the toy, while only 46% in the robot dog condition (N = 28) showed peeking behavior. To further analyze if there was a significant difference between children's peeking behavior between the three conditions, a Chi-Square analysis was conducted. Results revealed no statistical significant difference between the conditions.

Verbal behavior analysis

The verbal behaviors analysis consisted of two aspects. First of all, the presence of semantic leakage was assessed. An example that clearly illustrates the semantic leakage concept, and that frequently occurred during the experiments was that some children guessed immediately that the toy was a yellow duck. Of course, it was highly unlikely that the children figured it out by themselves, without peeking at the toy while the experimenter/robots were absent from the room. Subsequently, the experimenter asked whether the children peeked at the toy, and most declined and lie about it. The second analysis focused on finding possible differences on children's verbal responses, in particular in exploring possible differences in children's verbal responses between the three conditions, and possible variations in children's mean pitch while interacting with different robots versus a human.

Semantic Leakage

In the present study, from all the children that peeked at the toy when the experimenter/robot was absent (N = 50 in the 3 conditions), the majority (98%) showed semantic leakage. This means that they were inconsistent while producing false statements, showing that they knew information about the object (duck) that they could not guessed unless they looked at the toy. Furthermore, most of them (89%) lied and denied their peeking behavior, particularly children lied more to the robots (92% in the robot dog condition and 95% on the humanoid condition) than to the human (77%). However, there was no significant difference found in leakage behavior between the conditions, according to Chi-Square analysis.

Verbal Responses

Regarding the verbal response analysis, the initial focus was whether the children gave or not a verbal answer to the question: *"Did you peek at the toy?"*. Once again, a Chi-square analysis was performed, and revealed a statistical significant difference between the three conditions (x^2(2, N = 85) = 13.29, p < .001). As showed in table 1, it is clear from the results that children gave more verbal responses in both robot conditions (robot-dog: M= .79, SD=. 42 and humanoid M= .77; SD= .43) than in the human condition (M= .37, SD= .49). Additionally, when only focus on the children that peeked at the toy (and also gave a verbal answer to the question), the difference between the three conditions is still significant (x^2(2, N = 50) = 7.40, p < .05) as showed in table 2. Once again, children gave on average more verbal responses towards the robots (robot-dog: M= .85, SD=. 38 and humanoid M= .75; SD=.44 and human: M= .41, SD= .51).

Table 1: Chi-square results of the verbal response to the question "Did you peek at the toy?" in the 3 conditions (N=85)

Condition	N	Mean (SD)	x^2 Stats
Robot dog	28	.79 (.42)	x^2(2)= 13.29 ***
Humanoid	30	.77 (.43)	
Human	27	.37 (.49)	

****p < .001*

Table 2: Chi-square results of the verbal response to the question "Did you peek at the toy?" from the children that peeked at the toy in the 3 conditions (N=50)

Condition	N	Mean (SD)	x^2 Stats
Robot dog	13	.85 (.38)	$x^2(2) = 7.40$ *
Humanoid	20	.75 (.44)	
Human	17	.41 (.51)	

**p < .05*

These results stimulated further analysis. And therefore, the utterances after the question *"did you peek at the toy?"* were selected for pitch analysis. The means of the pitch values were computed using a Praat script. However, because the participants were children, adjustments in the default parameters were performed. The floor was set on 200 hertz while the ceiling was set to 600 hertz, which seem to be the reference values for children pitch analysis (Boersma & Weenink, 2016). The time step used for all the files was 0.01 seconds (i.e. the software computed 100 pitch values per second).

For the current analysis, only the children (N = 55) that gave a verbal response were taken into account. To explore possible differences in the mean pitch between the three conditions, a one-way ANOVA was conducted. Interestingly, results revealed a statistical significant difference ($F(2, 52) = 7.47$, $p < .05$, $\eta^2 = .223$) as depicted on table 3. Tukey post-hoc comparison revealed that the mean pitch in the robot dog (M= 262.88, SD= 37.01) and humanoid (M= 308.00, SD= 46.02) conditions were significantly different, i.e. the mean pitch of the participants in the humanoid condition was significantly higher than the mean pitch of the children in the robot dog condition. No significant differences were found between the robot conditions and the human condition (M= 271. 56, SD= 33.60).

Table 3: Anova results from the mean pitch of the verbal answers to the question "Did you peek at the toy?" in the 3 conditions (N=55)

Condition	N	Mean (SD)	*F* stats
Robot dog	22	262.88 (37.02)	F(2, 52) = 7.47*
Humanoid	23	308.00 (46.02)	
Human	10	271.56 (33.60)	

**p < .05*

Furthermore, because there was a significant difference between both robot conditions, it was also analyzed if a possible dissimilarity was present when the children's peeking behavior was taken into account. Once again, a one-way ANOVA was performed, and again there was a strong difference between the robot conditions as shown in table 4 ($F(2, 30) = 7.75$, $p < .005$, $\eta^2 = .341$). Tukey post-hoc comparisons revealed again the trend previously observed – the children from the humanoid condition (M= 314.84, SD= 49.10) had statistically significant higher mean pitch than those in the robot dog condition (M= 252.70, SD=25.17). Once again no statistical significant difference was found between the human condition (M= 275. 37, SD= .39.10) and both robots.

Table 4: Anova results from the mean pitch of the verbal answers to the question “Did you peek at the toy?” from the children that peeked at the toy in the 3 conditions (N=33)

Condition	**N**	**Mean (SD)**	***F stats***
Robot dog	11	252.70 (25.17)	F(2, 30) = 7.75**
Humanoid	15	314.85 (49.11)	
Human	7	275.38 (39.11)	

***p < .005*

Nonverbal behavior analysis

This analysis focused on facial cues that children exhibited after the question “*Did you peek at the toy?”*.

Automatic facial expressions analysis

In order to further understand if facial expressions differ across the conditions, an automatic facial analysis was conducted. To achieve this, the Computer Expression Recognition Toolbox (CERT) was used (Littlewort et al., 2011). CERT is designed to automatically detect facial expressions in video sequences. For every frame in a video fragment, CERT calculates the possible presence of the basic emotions – surprise, joy, anger, disgust, fear, sadness and contempt; but it also detects and measures the head pose (yaw, pitch, and roll), and the presence of 30 action units (AU’s) from the Facial Action Coding System (Ekman, 1976).

For the present analysis, the same video clips that follow the question “*Did you peek at the toy?”* were used. For CERT analysis, the prototypical emotions, and specifically, four action units were selected. The AU’s used were - cheek raise (AU 6), chin raise (AU 17), lip tightening (AU 23) and lip pressor (AU 24). The reason for this was because literature has shown that these AU’s are the most reliable indicators of deception in adults (DePaulo et al., 2003).

For every frame in each video clip, CERT calculated the possible presence of the prototypic emotions and action units. After that, for each clip, the mean probability regarding the presence of the basic emotions and AU’s was computed. The reason for this was related with an attempt to improve any possible CERT flaws during the data extraction due to, for instance, quick movements or possible blurriness in the clips.

According to table 5, a one-way ANOVA showed that there was a significant effect in AU 6 - cheek raise ($F(2, 49) = 3.91$, $p < .05$, $\eta^2 = .137$), when consider all the children that gave a nonverbal reaction independent of having peeked or not at the toy. A Tukey post-hoc comparison showed that AU 6 (cheek raise) in the robot dog condition (M= .25, SD= .28) was significantly more present than in the human condition (M= .04, SD= .19). However, no significant difference was found between the humanoid (M= .11, SD= .18) and the robot dog, or with the human condition. Additionally, all other action units did not show statistical significant differences between the conditions.

Table 5: Anova results for the AU6 - cheek raise - from children that gave a nonverbal answer to the question “Did you peek at the toy?” in the 3 conditions (N=52)

Condition	**N**	**Mean (SD)**	***F* Stats**
Robot dog	17	0.25 (0.28)	F(2, 49) = 3.91*
Humanoid	16	0.11 (0.18)	
Human	19	0.04 (0.19)	

**p < .05*

In addition, a statistical analysis was performed in order to explore possible differences in emotions across the 3 conditions. Interestingly, as shown in table 6, only joy appeared to have a significant effect according to a one-way ANOVA ($F(2, 49) = 4.80$, $p < .025$, $\eta^2 = .171$), while no distinction was made between the children that peeked at the toy and the ones that did not. A Tukey post-hoc comparison revealed a significant difference between the robot dog (M= .03, SD= .04) condition and the human condition (M=.00, SD= .00). However, no differences were found between the humanoid (M= .01, SD= .02) and the other two conditions.

Table 6: Anova results of joy from children that gave a nonverbal answer to the question “Did you peek at the toy?” in the 3 conditions (N=52)

Condition	**N**	**Mean**	***F* Stats**
Robot dog	17	0.03 (0.04)	F(2, 49) = 4.80*
Humanoid	16	0.01 (0.02)	
Human	19	0.00 (0.00)	

**p < .05*

Lastly, the presence of action units and emotions was further investigated within the children that only responded nonverbally to the question about whether they had peeked at the object. As shown in table 7, a one-way ANOVA revealed that the presence of joy differ between the robot dog and the human condition: $F(2, 25) = 5.82$, $p < .05$, $\eta^2 = .313$. Tukey pairwise comparison showed that in the robot dog condition (M=. 04, SD= .05) children seemed to express more joy compared to the human condition (M= .00, SD= .00).

Table 7: Anova results of joy from children that only gave a nonverbal answer to the question “Did you peek at the toy?” in the 3 conditions (N = 28).

Condition	**N**	**Mean (SD)**	***F* Stats**
Robot dog	6	0.04 (0.05)	F(2, 25) = 5.82*
Humanoid	6	0.01 (0.01)	
Human	16	0.00 (0.00)	

**p < .05*

Discussion

The main goal of the current study was to compare children's lying behavior in interactions with different types of robots, and with human partners. To achieve this, a temptation resistance paradigm was used, which was inspired by previous work (Lewis et al., 1989; Talwar et al., 2007; Talwar & Lee, 2002b; Talwar & Lee, 2002a). In the present study, children were given the opportunity to peek at a toy (although they were told not to peek), and to lie about their behavior in order to win a prize. Of the 85 children with a valid response, 50 (58.8%) showed a backward glance. This result is very similar to a previous study in which children showed a similar percentage of peeking behavior (Talwar et al., 2007). Moreover, this study showed that there is no difference when children interact with humans or with different types of personified robots regarding peeking behavior, i.e. children in all conditions peeked as frequently to the toy. However, despite the similarity in peeking behavior, we observed that children lied more to the robots then to human experimenter. Because lying has a moral (negative) valence attached to it (Talwar & Lee, 2002a), children might have considered that lying to robots was less harmful than lying to humans. In addition, children might have assumed that robots could not detect the lies so easily as humans. Furthermore, interacting with robots was probably more playful than interacting with a human, which could have taken away the negative valence of lying, and thus diminishing the threshold for children to lie.

In addition, the experiments in this study confirmed the presence of semantic leakage during a lie-tell. Semantic leakage means that during a lie-tell, children find it hard to keep the information of the initial lie consistent with follow-up statements. From all the children that peeked at the toy (N = 50), a majority of 98% was inconsistent in reproducing a false statement after lying about their peeking behavior, independent of the condition. And most of them (89%) lied about their peeking behavior. These results go in line with a previous study, in which children between 3-5 years old showed a poor control of semantic leakage (Talwar and Lee, 2002a). Furthermore, this lack of semantic control provides evidence that in order to successfully lie, children need to have their first order and second order beliefs in ToM fully developed. The semantic leakage found in the present study shows that children between 4-6 years old do not have ToM completely developed, which is also supported by earlier findings (Talwar et al., 2007).

Turning to the results of the verbal analysis, we found that children of 4 -6 years old gave more verbal responses to robots in comparison with the human condition. A possible explanation for this might be that the robots were rather static and gave less interactive cues (e.g. facial expressions and body expressions), and that children therefore tried to overcompensate this lack of feedback by their responses in order to convince the robots (dog or humanoid) of their desired behavior.

This study also showed that the children's mean pitch differed between the robot conditions. This result goes partly in line with previous findings that suggested that pitch can change during a lie-tell (Streeter et al., 1977). One unanticipated finding was that, in the humanoid condition, the mean pitch was significantly higher in comparison with the robot dog condition. A possible explanation for this might be that children did not feel a strong need to convince the robot dog, because it is not human, and does not resemble any human shape. And their lower pitch could also be interpreted as a sign that children were more relaxed during interactions with the robot dog.

According to this study, children between the ages of 4 - 6 years showed more joy when interacting with robots, specifically when interacting with the robot dog (in line with the pitch results). It can be argued that children found the robot dog playful and were happy while interacting with it. Consequently, the seriousness of the experiment might have been taken away because of the particular shape of the robot, i.e. a dog. Furthermore, these results seem to be consistent with previous findings that found that children that showed an interest in a Lego robot also enjoyed interacting with it (Cook et. al, 2011). Moreover, the results indicate that children tend to attribute social features to a robot dog, which is in line with a previous finding (Melson et al., 2009). Likewise, the new finding about the variation in AU 6 – cheek raise, supports the findings about joy while interacting with robots. Au 6 is one of the AUs that signals happiness/joy. This finding is also in line with previous studies about children's lying behavior, in which children showed more positive nonverbal cues during a lie tell, such as smiles and a more positive attitude (Feldman et al., 1979; Lewis et al., 1989).

Finally, one limitation of this study is that the robots used were LEGO EV3, and children may have seen the robots as toys (because it is made of Lego); and maybe not as fully autonomous entities because there were some flaws in terms of full interactivity. For instance, they were not build up for rich conversations, and they were not able to (re-)enter the room autonomously (see methodology).

Conclusion

The present study led to a series of new findings regarding the way children interact with robots, how this compares with humans, to what extent the robot type matters, and how children attribute specific mental states to their artificial and human partners. In particular, we have explored deceptive interactions in various interaction types, which revealed differences in correlates of trust and behavioral patterns. More specifically, the present outcomes of our study contribute to the understanding of child-robot interaction, and to the comprehension of children's deceptive skills towards robots. Furthermore, the findings have significant implications for the understanding of how robots can be used for lie elicitation and lie detection, specifically with children.

In future studies it would seem useful to explore a wider range of audio cues and their validity for lie detection, since this study demonstrated that children tended to show an abundance of verbal cues, especially when talking to robots. Finally, it would seem a nice idea to explore whether children behave differently towards other types of robot as well (such as NAO and ICat), given our result that children's beliefs about robots and how they deceive to them may vary as a function of the shape, appearance and human-like features of the robot partner. Finally, the findings about children's ToM towards the robots can also be a valuable insight when designing robots that can be involved in children's daily tasks, such as the ones involved in persuasive games and learning tasks.

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5

A perceptual and behavioral analysis of facial cues to deception in interactions between children and a virtual agent

Abstract

This study focused on the facial expressions that children exhibit while trying to deceive a virtual agent. An interactive lie elicitation game was developed to record children's facial expressions during deceptive and truthful utterances. Our participants did this task either alone or in the presence of peers. A manual method and an automatic recognition approach were used to examine facial expressions and facial action units (AUs). Results show that the facial expressions of deceivers differ from those of truth-tellers: most clearly, they try to cover their lie as they smile significantly more often than truthful children. Moreover, co-presence enhances children's facial expressive behavior and the number of deceptive cues. To understand whether such features serve as cues for deception detection, using data from children playing alone or together with another child, a perception test was carried out to examine observers' ability to distinguish young deceivers from truth-tellers. Results show that observers found it easier to discriminate between deceivers and truth-tellers who had played the game in the co-present condition. Our research thus shows that virtual agents can be used as tools to elicit lies in a playful manner, which would be relevant for developmental, educational and behavioral analyses of deceit in growing children.

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Introduction

In the last decade, the use of socially intelligent agents has increased substantially, especially in the life of growing children. Because of the social nature of these agents, research-driven solutions are emerging, e.g. in order to promote vocabulary learning (Tanaka & Matsuzoe, 2012), to stimulate science curiosity in classrooms (Shiomi, Kanda, Howley, Hayashi, & Hagita, 2015), to explore social bonding between children and social robots (Belpaeme et al., 2013), or to study turn-taking in a game situation (Andrist, Leite, & Lehman, 2013). There has also been a more specific interest to use such agent in health related areas, such as in interactive animations to support families that have children under-go cancer treatment (Marsella, Johnson, & Labore, 2000), or to the development of applications that help autistic children in training their social and learning skills (Parsons, 2015; Ramachandiran, Jomhari, Thiyagaraja, & Maria, 2015). Given such implementations, socially intelligent agents are designed to build relations with children and to bring an added value to their life. However, the wide-ranging use raises the question regarding the nature of the relationship children can build with their artificial partners, and the mutual trust children experience in their interactions with them. As a matter of fact, artificial deceptiveness (Westlund, Breazeal, & Story, 2015), from the child to the robot, and vice versa, raises several concerns, in as far as social robots can influence the way children behave and see the world (Severson & Carlson, 2010). An interesting issue regards the extent to which children feel their addressee can judge the child's mental state, and whether they perceive a difference in that respect between human and artificial partners. Also, as we argue below, if we understand better how children experience their relation with these social agents and how this compares with their relation towards other human beings, this would give us an opportunity to use such agents as tools for the study of lie behavior. This is particularly interesting as there is a growing awareness that children's deceptive behavior is extremely indicative of their general psychological development. Specifically, the scientific interest in children's deceptive behavior is motivated by two factors. First, deceptive behavior has been defined as an important milestone in children's development, i.e., it is considered a prerequisite for the acquisition of an adequate social behavior (Fu, Evans, Xu, & Lee, 2012; Talwar & Crossman, 2011; Talwar & Lee, 2002a, 2002b). This means that within a typical development, children are supposed to have the "skill' to lie at a certain age, and curiously this happens around the same period of development across cultures (Talwar & Crossman, 2011) (Talwar & Crossman, 2011). Secondly, the similarity in children's deceptive behavior is believed to shed light on universal properties regarding the development of Theory of Mind (ToM) (Talwar, Gordon, & Kang, 2007; Talwar & Lee, 2008), working memory (Alloway, McCallum, Alloway, & Hoicka, 2015), and executive functioning skills (Lee, 2012).

Whereas a significant amount of work has been focusing on child-robot interaction (Belpaeme et al., 2013; Breazeal et al., 2016; Kory Westlund et al., 2017; Severson & Carlson, 2010), child-virtual agent interaction have received far less attention. Particularly, it is still unclear whether results obtained from studies with robots would generalize to virtual agents as well, especially when it comes to the way children trust and believe these agents. In a prior study (Serras Pereira, Nijs, Shahid, & Swerts, 2016), we showed that children lie as often to robots, such as a humanoid or robot dog, as they do to a human partner, yet there were also specific differences, depending on the type of interaction partner. Children were more talkative towards the robots (a robot dog and a humanoid) than when interacting with a human. And, children appeared happier when they were interacting with the robot dog compared to what was the case with the humanoid or human partner. This suggests that children's communicative style, and thus also the extent to which they are able or tend to deceive, can be affected by the kind of artificial partner they interact with.

Those differences may well relate to the degree to which children's Theory of Mind (ToM), i.e., the capacity to attribute mental states to another individual, and to recognize the existence of different perspectives (between one's own perspective and that of the other), varies as a function of the type of artificial communication partner, and the channel that it is used to communicate. For instance, a previous study (Kahn, Friedman, Pérez-Granados, & Freier, 2006) showed that children attempted more to build rapport with an AIBO robot-dog and showed more apprehensive behavior than when interacting with a stuffed dog, in which more mistreating behaviors and animation attempts were performed. Since virtual agents are being used in many different interactive applications (mobile and desktop), in which they are represented both as the main source of gameplay (e.g. talking tom[3]), and as facilitators (e. g. 3d characters that help students in learning (Mohamad, Velasco, Damm, & Tebarth, 2004)), an interesting question worth to be explored is if children behave similar as they did towards the robots, when trying to deceive virtual agents, that are more expressive in their communication style (even when the interaction is mediated by a screen), and how this compares to deceptive interactions with a human partner.

In order to tackle such issues, it is relevant to first focus on what we know about lying in human-human interactions. Over the years, the interest in cues that point to deception has grown, but there remain different uncertainties with regard to children's deceptive behavior (Talwar, Crossman, Gulmi, Renaud, & Williams, 2009). Those studies in which children were analyzed tended to focus on the questions if, why and when children lie, usually without exploring their behavioral cues (Vrij, Akehurst, Soukara, & Bull, 2004). Moreover, not much is known about how the social setting may affect deception. For instance, there are only a few studies regarding children's nonverbal behavior during deceit in the presence of other people. This is particularly surprising for several reasons. First of all, lying is a social behavior that often occurs in the presence of more than one interactional social partner. Imagine the occurrence of lies in everyday life, when siblings or friends lie together in order to avoid punishment for inappropriate deeds. It is important to understand the characteristics of deception in the way it frequently occurs in everyday life (DePaulo, Kashy, Kirkendol, Wyer, & Epstein, 1996). Secondly, only a few studies exist that examined the ability to detect lies in recordings of pairs of children (rather than a single child) (Strömwall & Granhag, 2007a; Swerts, 2012; Vredeveldt & Wagenaar, 2013). Little is known about lying in pairs, and the nonverbal behavior that comes along with deceit in co-presence.

As mentioned, from a developmental perspective, learning to lie is an essential step in the development of a child's normative behavior, but at the same time raises certain moral concerns because it can have, occasionally, pervasive consequences (Talwar & Crossman, 2011). This dual nature makes deception a very relevant phenomenon to be explored in several different research areas, ranging from development areas to human-computer

[3] https://talkintomandfriends.com

interaction field, particularly for virtual games since deception often occurs in these settings, or is often a necessary behavior in a game. Consider, for instance, simple games where bluff is an essential game component, such as in dice games, where for example one has to guess if another player is truthfully referring to a number or not. Additionally, this kind of bluff game was also used in a previous study with children (Mahmud et al., 2007).

Apart from a more general interest into how social agents affect children's emotional and cognitive state and interact with them in different settings (Tanaka & Matsuzoe, 2012; Shiomi et al., 2015; Belpaeme et al., 2013; Andrist et al., 2013; Marsella et al., 2000; Parsons et al., 2015; Ramachandiran et al., 2015), there are also methodological reasons to use such agents in studies on social and deceptive interactions, in particular with children, especially in view of the fact that such agents are more accessible and as less expensive than robots. Indeed, social agents have different advantages in comparison with human partners, as they are always available, and possibly less intimidating than human dialogue partners, which could be important in juridical contexts. Moreover, whereas human behavior may vary in interactive contexts, social agents can be "programmed" so that they behave more consistent and systematic. The latter feature is particularly useful in research on deceptive behavior in which one would want to avoid, for reasons of consistency, that children's lying behavior varies too much as a function of characteristics of their human dialogue partner, as opposed to interactions with a virtual agent whose properties remain constant and whose interaction style can be fully controlled.

The present study is not only interested in the nonverbal expressive behavior of children while lying to a virtual agent but also investigates whether such cues are affected by differences in the social context, i.e., whether a child is alone or co-present with another. In particular, the focus of the analyses is on the face, because facial expressions are linked to children's mental state (Ekman & Friesen, 1976). In the following, we first describe previous studies regarding children and virtual agents, then discuss children's facial cues to deception, then review previous findings about deception and co-presence, and about lie detection. Finally, we embark on our own study where we first discuss in detail the lie elicitation paradigm we used, then the newly developed coding scheme to analyze the facial expressions. We then present our results, and end by reflecting on these and presenting future lines of research.

Related Work

Children and virtual agents

The increasing importance and impact of virtual agents in children's daily life has led to a new line of research into how children experience interactions with these artificial partners. In particular, on-going research (Tanaka & Matsuzoe, 2012; Shiomi et al., 2015; Belpaeme et al., 2013; Andrist et al., 2013; Marsella et al., 2000; Parsons et al., 2015; Ramachandiran et al., 2015) has been focusing on developing virtual agents that interact and communicate with humans in a realistic way, i.e., that have communicative patterns similar to the ones that humans use in daily life. One user group that has a potential to gain considerable benefits from the design of such agents is children. For instance, there are several situations of daily life where children face higher levels of anxiety and stress, in which the interaction with virtual agents could be beneficial. These situations are very wide, ranging from juridical context, such as in court cases where children are required as witnesses to communication difficulties, such as learning and tests at school, to more problematic behaviours, such as lying and bullying. For example, the TAPA (training with animated pedagogical agents) system was developed for children with cognitive impairments. In this system, the virtual agents are able to express several emotional behaviours with the aim to support and influence the children's motivation during the learning process (Mohamad et al., 2004). Other applications are teachable agents (Pareto, 2014) (i.e., learning technology designed to teach an agent to help students to learn) to teach arithmetic concepts and reasoning to children. In fact, results show that students that used teachable agents had a significant learning gain compared to children that used traditional methods for learning.

Additionally, virtual agents have also been exploited in other fields of research that are more directly connected to the goals of our current study. For example, (Segovia & Bailenson, 2009) explored how immersive virtual environment technology (IVET) elicits false memories in children, i.e., how memory was affected by visualizing dynamic avatars performing original actions. It is particularly interesting that virtual agents are able to elicit false memories in children, especially as these by their very nature seem to be (often) linked to lies. In fact, a previous study that compared lie telling behaviour between children with autism and children with typical development (Talwar et al., 2012) found that children with typical development lied more about their peeking behaviour compared to children with autism. Furthermore, children with autism had more difficulties in maintaining their lies, and lie-tellers had also higher scores on false beliefs tasks than truth-tellers. These higher scores have been previously associated with children's ability to maintain a lie (Talwar et al., 2007).

Children's facial cues to deception

Facial expressions are considered to be a window to the soul, in the sense that these subtle signs often reveal important information that may not always be clear from what a person is actually saying. In children, whose social, emotional and cognitive skills are not yet totally maturated and who may not always be able to verbalize their inner emotions, facial expressions can be even more a relevant and potential source of information when investigating deceptive behavior. In fact, research into children's facial expressions showed that children try to control their facial expressions in order to cover their deceit (Talwar, Murphy, & Lee, 2007), even when there appear to be systematic differences between young lie- and truth-tellers, though results between studies are not always consistent. For instance, according to a study (Talwar & Lee, 2002a) in which children's facial expressions were examined during a deceptive statement, children smiled significantly more when they stated that they did not peak, even though they had actually done so (38% smiling), compared to children who told the truth (11% smiling). Big smiles as well as small smiles were shown more often by lie-tellers. In contrast, another study (Talwar & Lee, 2002b) found that when three-year-old children tell white lies in a politeness situation, truth-tellers displayed significantly more big smiles than lie-tellers and seemed less confident. These results are consistent with the finding that nonverbal leakage control and the ability to deceive increases with age (Saarni, 1984; Talwar et al., 2007; Talwar & Lee, 2002b). Furthermore, it was found that white lie-tellers who receive an undesirable gift smiled more than children who receive a desirable gift, presumably to convince people that they actually like the gift (Talwar et al., 2007). Accordingly, it can be expected that deceivers raise their positive expressive behavior (e.g.

smiling) in order to compensate a lie and cover deceit (Talwar et al., 2007; Talwar & Lee, 2002a). However, besides smiling research showed that lie-tellers press their lips more often than truth-tellers (DePaulo et al., 2003; Talwar & Lee, 2002a). In a previous study (Talwar & Lee, 2002a) liars also exhibited a significantly less relaxed mouth expression in addition to their smiles. The pressing of the lips can be seen as a leakage cue, which shows that children try to suppress the actual feelings related to their lie.

Other studies have focused on eye gazing behavior of young deceivers. In the study of Talwar and Lee (2002a), both lie-tellers and truth-tellers looked at the experimenter, but in addition deceivers looked significantly more often away or down in comparison with truth-tellers. Another study (McCarthy & Lee, 2009) confirmed these results with the finding that children maintained significantly less eye contact and looked more often away during their deceit. However, in this study children who lied looked significantly more upward, not downward during their deceit. Interestingly, differences in eye gazing were only significant until the age of nine. The differences in eye gazing between truthful and deceptive children disappear among children who are older than nine years old. This can be explained by the fact that the ability to lie develops with age (Saarni, 1984; Talwar et al., 2007; Talwar & Lee, 2002a).

In addition, cues to deception seem to depend on other variables, such as the awareness of the deceptive attempt and motivation to succeed (DePaulo et al., 2003; Swerts, van Doorenmalen, & Verhoofstad, 2013). One of these studies found that children showed more cues to deceit in their second attempt compared to their first attempt (Strömwall &Granhag, 2007). Other research suggested that deceptive cues are less likely to occur when the liar is not motivated, and the stakes are low (DePaulo et al., 2003; Mann, Vrij, & Bull, 2002). In addition, individual differences turned out to be related to the expression of nonverbal behavior during deception (Mann et al., 2002; Riggio & Friedman, 1983).

Another variable that affects nonverbal expressive behavior of children is co-presence (Vredeveldt & Wagenaar, 2013), i.e., children's behavior is affected by the presence of other persons in the same situation, and the way that they interact (with each other) is also an influential factor. Results on this topic are described in the following section.

Deception and co-presence

As mentioned above, when investigating children's deceptive behavior, it is also important to consider the social context in which such kind of behavior occurs. It is often the case that children's deceptive behavior happens in co-presence. Consider school settings, where often children lie together with peers, in order to avoid punishment, or siblings' situations where conflicts and lies about misdeeds are part of daily life. In fact, according to previous studies children express different nonverbal behaviors when they are in the presence of others, compared to when they are alone (Vredeveldt & Wagenaar, 2013; Wagner & Lee, 1999). A previous study investigated the effects of co-presence on children's emotional expressions during a game play. In this case, children played a game either in pairs or alone, and it turned out that children who play a game in pairs were more expressive than children who play alone (Shahid, Krahmer, & Swerts, 2008).

Despite the considerable number of studies regarding the effects of co-presence on nonverbal behavior, to date, only a few studies focused on the link between deceptive behavior and co-presence. For instance, a study (Strömwall & Granhag, 2007) examined adults' ability to distinguish pairs of truthful and deceptive children. Children were interviewed about a real or an imagery encounter with a stranger. Results showed that in general the overall lie detection accuracy was higher (62.5%) than chance level (50%). Moreover, lie detection accuracy was greater when watching both children simultaneously than when watching one child separately. In a similar vein, another study investigated the extent to which pairs are verbally consistent in their testimonies of experienced and imagined events (Vredeveldt & Wagenaar, 2013). The verbal consistency of pairs was significantly higher when children told statements about an experienced event, compared to statements about an imagined event. When pairs told about imagined events, they contradicted on approximately two out of three statements compared to one out of three for experienced events. Finally, the origin of blue lies, i.e., the ability to lie to benefit the group/collective, was also examined in children (Fu, Evans, Wang, & Lee, 2008). In this study, children between 9-11 years old were placed in a real-time situation in which they could decide to lie in order to conceal the group's cheating behavior. Results showed that not only children tended to endorse more lies, but also lied more to protect the group as aged increased.

In short, it seems that co-presence can not only influence children's nonverbal behavior, but it can also play a significant role in the way children express deception. However, little is known about how this is expressed during interactions with socially intelligent agents. Secondly, to the best of our knowledge no study has been conducted to explore the nonverbal expressions of children during deception in the co-presence situations. Moreover, no study focused on eliciting deception using virtual agents in co-presence settings. Based on what is described above, one could argue that children probably leak more nonverbal cues during a lie tell when in co-presence of a peer. Therefore, it seems relevant to explore how children express deception in co-presence towards virtual agents.

Finally, if co-presence enhances nonverbal expressions during a lie tell, it seems relevant to further explore the impact of this in terms of lie detection. In the following section, we briefly described some of the few studies that examined the judges' ability to distinguish paired lie- and truth-tellers based on their nonverbal expressive behavior.

Lie catching

Even though previous research showed evidence of nonverbal cues that signal deceptive behavior, lie detection remains a complex task. Studies about lie detection based on nonverbal behavior showed that lie-catchers often score below or only slightly above chance level (Ekman, 2009; Vrij, Akehurst, & Knight, 2006) even in cases where the lie-tellers are children. For instance, a study (Talwar & Lee, 2002a) showed that adult evaluators failed to detect lie-tellers above chance level solely based on the children's nonverbal behavior. In another study, a group of evaluators was asked to watch the clips of children's nonverbal behavior during truthful and deceptive statements about peaking. The evaluators were able to accurately differentiate clips of lie-tellers above chance level (55% accuracy), but unable to accurately differentiate clips of truth-tellers (46% accuracy) (Talwar et al., 2009). Another study found that judges are able to distinguish between clips of deceptive and truthful children above chance level, based on full body nonverbal behavior (Serras Pereira, Cozijn, Postma, Shahid, & Swerts, 2016)

Other studies focused on the ability to distinguish deceptive and truthful pairs of children. In particular, one study (Swerts, 2012) investigated if observers were better able to detect deception when children were in co-presence of a peer during their deceptive attempt. On average, the number of accurate detections was higher in the paired condition (60.6% accuracy) than in the individual condition (58% accuracy). However, the study did not find a significant main effect of co-presence. Another study investigated if undergraduate students were able to classify lie-telling and truth-telling adult pairs and individuals (Strömwall, Granhag & Jonsson, 2003). Observers had to differentiate between pairs that told a truthful story or fabricated an alibi during a police interrogation. Even though lie-catchers performed above chance level in their first judgment (62% accuracy), the overall detection of liars was modest. In addition, the lie-catchers were asked how they assessed the honesty of pairs and it turned out that their evaluation was based on the consistency between pairs.

In conclusion, earlier research suggested that the chances to recognize deception with the unaided eye are small, but co-presence may increase the amount of cues that point to deception in children.

Present Study

The present study explores children's lying behavior towards virtual agents by using a lie elicitation paradigm. In particular, facial expressions are examined during deceptive and truthful utterances, and between paired and individual children to learn more about the effect of co-presence in relation to lying behavior towards a virtual agent. The reason for this is twofold: first, earlier research proved that young children smiled more during a deceptive attempt in order to cover their deceit (e.g. (Talwar et al., 2007)) Secondly, children have been shown to become more expressive in co-presence of a peer (Shahid et al., 2008; Wagner & Lee, 1999) Consequently, it can also be expected that the exhibition of positive expressive behavior (i.e. smiling) during a deceptive attempt will increase in co-presence (Talwar et al., 2007). Additionally, if children become more expressive when another child is co-present, this may make it easier to detect whether the child is lying. The present study also investigates to what extent adult observers can distinguish between truthful and deceptive pairs and individuals.

Data recording

Lie Elicitation Paradigm

First of all, in order to study children's deceptive facial expressions towards a virtual agent, a child friendly elicitation game called 'Princess Lilly in Space' was developed using the GoAnimate software[4] . In this elicitation game, children were invited to help a virtual agent (a princess called Lilly) by deceiving an evil astronaut (another virtual agent) who wanted to take over her spaceship. The game started with a warming-up task and an introduction to make the children familiar with the experimental procedure. In the warming-up task, children had to call princess Lilly to make contact with the spaceship and subsequently princess Lilly reacted with the sentence 'O hey, hey, we are in contact now' after which she asked for the name/names of the children. Next, princess Lilly reacted with the sentence 'that is/are (a)

[4] https://goanimate.com.

pretty name(s)', 'I hope I will see you soon' and disappeared. Then, the evil spaceman introduced himself when entering the spaceship. Subsequently, a narrator explained the story plot and described the characters in more detail. The narrating voice introduced the story as a fairy-tale plot, i.e., the narrator explained that there was an evil astronaut that wanted to take princess Lilly's spaceship. The narrator asked the children to help Princess Lilly, and told them that if they were successful in this task the children would get a reward (stickers).

The idea to create a fairy tale plot was an attempt to persuade children to engage in a friendly way, in line with a comparable paradigm used in a previous study (Swerts et al., 2013). In order not to run into unethical issues and to avoid that children would feel bad afterwards, we have set up the game in such a way that children only lied "for a good cause", namely to save princess Lilly, which also increased the fun factor for them.

After the omniscient narrator explained the story, the game started, and princess Lilly asked the children to help her by deceiving the evil astronaut. She asked the children to tell the evil astronaut that she would hide behind door one or door two, while in reality she ran further and hid somewhere else (i.e. 'When he comes, will you say that I am hiding behind door one in the control chamber or door two in the engine room?'). After princess Lilly had rushed away, the evil astronaut appeared and asked where the princess was hiding (i.e. 'Will you tell me where she is?). This way, the children were given three options: deceive the astronaut by telling that princess Lilly hid behind door one in the control chamber (i.e. deceptive option 1a), or deceive the astronaut by telling that princess Lilly hid behind door two in the engine room (i.e. deceptive option 1b), or tell honestly that princess Lilly ran further and hid somewhere else (i.e. alternative option). In other words: children had to make a conscious decision about whether or not to deceive the evil astronaut. In addition, the children had to think about their lie, because they had to choose between one of the two doors. When children told the truth (i.e. alternative option) the game ended, and the evil astronaut took over the spaceship. If they chose to deceive the astronaut, the evil astronaut asked the children where princess Lilly went. After the children had answered, the evil astronaut would ask: "You are not fooling me, are you?" in order to provoke an extra deceptive statement. And after this, the evil astronaut went way looking for Princess Lilly. Then, princess Lilly returned on stage and asked the children what they had told the evil astronaut (i.e. truthful option). In this way, the game elicited a deceptive and a truthful utterance from paired and individual children. At the end of the game, the princess thanked the children for their help and the narrator explained that the children did very well and deserved the reward that was promised at the beginning of the game. Figure 1 provides a visualization of three different scenes of the elicitation game.

Participants

Forty-Nine participants (25 boys, 24 girls) in the age range of 5 to 7 years old (*M*= 6.05) participated in this study. The participants were recruited from group 3 of an elementary school in The Netherlands, and consent forms authorizing children's participation were collected from all the children's parents. Through the consent form they agreed that a child was allowed to participate in the study and that their video material could be used for scientific purposes. Solely children with an approved consent form were allowed to participate in the study. Unfortunately, one boy did not succeed in playing the game (as he did not understand how to play the game) and had to be removed from the sample, so that we retained a sample of 48 participants.

Procedure

Prior to the experiment, children were randomly assigned to the paired or individual condition, resulting in pairs that consisted of children of the same or different gender. Each experiment lasted approximately 7 to 10 minutes and consisted of a briefing, warming-up, the actual game and a debriefing. At the beginning of the experiment, children were welcomed by the experimenter and asked to step on a cross on the ground in front of a television screen that displayed the elicitation game. Pairs were asked to share the cross and stand next to each other, while individuals were asked to stand alone on the cross.

Figure 1: Different scenes of the elicitation game 'Princess Lilly in space

Note that pairs had to play a practice game prior to the elicitation game that was developed to make sure both children in the paired condition would be active during the elicitation game. In the practice game, pairs were asked two simple questions and given two simple response options (i.e. A or B). The questions were sequentially: 1. Where do cows live? A. On the farm, B. In the dessert. 2. Where do fish live? A. In the air, B. Underwater. Pairs had to deliberate shortly before giving an answer together. This way pairs got familiar with the process of deliberating and answering together. The practice game was implemented in order to avoid that only one child of a pair would respond in the actual experiment. Subsequently, both pairs and individuals were given the same instructions. In the end, all children were debriefed but also probed for suspicion by asking what the purpose of the game was. Most of the children answered 'to help the princess', and none of them signaled any suspicion. All 48 children lied to the evil astronaut, mentioned during debriefing that they really enjoyed participating, and in the end, they all received a small reward (i.e. a colorful marker) as a token of appreciation.

Materials

The elicitation game was presented in front of the children on a Philips HD television screen that was connected to a MacBook Air. In addition, two Panasonic Full HD cameras were positioned on tripods in front of the child/children next to the television, which recorded full body video of the children during the gameplay. Paired children were recorded together simultaneously in one shot.

Data Preparation

The truthful and deceptive statements were cut and cropped to: 1) separate clips for the truthful and the deceptive condition; 2) to make sure that only the face of the children is visible for the analysis. In the paired condition, the face of each child was cropped individually to guarantee that the faces could be analyzed in isolation. For the purpose of the present research audio was not included in the clips.

Study 1

In this study the facial expressions that children exhibited during deceptive and truthful utterances were analyzed using a manual method. The durations of the facial expressions were encoded manually using a coding scheme (discussed in the data analysis section).

Design

This study used a 2x2 mixed design, with the independent variable deception (i.e. truthful or deceptive) as a within-subjects factor, and the independent variable co-presence (i.e. paired or individual) as a between-subjects factor. In total, there were 18 children in the individual condition and 15 pairs (30 children) for the co-presence condition. The dependent variables of Study 1 were the durations of the facial expressions that children displayed in milliseconds.

Data analysis

In order to analyze the data on the basis of an objective measure, a coding scheme was developed on the basis of existing literature and the Facial Action Coding System (FACS) (Ekman & Friesen, 1976)(see appendix A). The durations of the nonverbal facial expressions – gaze aversion, blinks, big smiles, smiles and pressed lips --were measured for each child in both conditions (i.e. deceptive and truthful condition) separately. Figure 2 gives an overview of these facial expressions. To increase the reliability of the coding process, a second coder who was unaware of the purpose of the experiment coded the clips of 30 out of 48 children, representing about 60% of all recordings. Subsequently, the agreement between the two coders was assessed for the frequencies of the encoded facial expressions. The intercoder agreement was assessed with Cohen's Kappa and yielded a reliable agreement between the coders (k = .83). Differences between coders were solved by re-examination of the clips together.

It is important to note that pairs received an adjusted score in order to compare the amount of facial expressions exhibited in the paired condition with the amount of facial expressions exhibited in the individual condition. The durations of the expressions exhibited by pairs (i.e. two individuals) were added and divided by two (i.e. averaged) for each facial expression separately. Another possibility to compare the expressive behavior of paired children with individuals would have been to measure the expressions of only one of the two children, or to make a distinction between children on the left and on the right in the paired condition. The latter options were however not preferable, because research proved that the nonverbal expressive behavior in co-presence of a peer is dependent on the specific characteristics of the present peer. Specifically, consider the chameleon effect and the transactional process that takes place among pairs (Chartrand & Bargh, 1999). Besides, a significant amount of data would be lost if the facial expressions of only one of the two children in the paired condition were measured.

Figure 2: Most important facial expressions related to deceit according to previous research, exhibited during the elicitation game.

Results

Before the main analysis, the normality of the dependent variable was tested in each condition (i.e. deceptive and truthful condition) for pairs and individuals. In order to test for normality, skewness, and kurtosis, the Kolmogorov-Smirnov test scores were assessed (the normality statistics can be found in Appendix B, Table 1). The normality scores pointed to a severe deviation from normality, as one Kolmogorov-Smirnov test was significant and there was a slight sign of skewness for pairs in the truthful condition. However, given that there is no Bootstrap with Confidence Intervals function available for the Factorial ANOVA with Repeated Measures, the *p*-value should be interpreted with some caution, even when deviations from normality have been argued not to be too problematic for Anova's (Hays & Hays, 1973). Subsequently, a Repeated Measures ANOVA was conducted to analyze the differences in positive nonverbal cues (i.e., smiles) between truth-tellers and deceivers, and to analyze whether paired deceivers showed more of these cues (i.e. smiles) than individual deceivers. Results showed a significant main effect of deception on the time children spent smiling ($F(1, 31) = 13.895$, $p = .001$, $\eta 2 = 31$). There is a difference in the mean duration of smiles between the deceptive ($M= 3892.5$, $SD= 4469.6$) and truthful condition ($M= 1533.5$, $SD= 1926.1$). This indicates that children smiled more (milliseconds) in the deceptive condition than in the truthful condition. In addition, there was a significant interaction effect between deception and co-presence ($F(1, 31) = 6.432$, $p = .016$, $\eta 2 = .17$). In the deceptive condition, paired children ($M = 5921.9$, $SD = 5826.2$) smiled more than individual children ($M = 2201.2$, $SD = 1728.6$).

In addition, to see if children who are in co-presence of a peer show more facial expressions than individuals, a Mann-Whitney U Test was performed, which is the non-parametric counterpart of the Independent Samples T Test. The reason for using this test was that when assessing the normality scores for the dependent variable (total durations that children expressed facial expressions in milliseconds) for pairs and individuals, the Kolmogorov-Smirnov test pointed to a severe deviation from normality for individuals (the normality statistics can be found in Appendix B, Table 2). Further inspection showed that extreme outliers caused the non-normality. The reason was that some children exhibited hardly any facial expression, while other children were very expressive. The boxplot on Figure 3 represents the durations of facial expressions exhibited in the individual and paired condition. Results showed that the exhibition of facial expression (in milliseconds) was higher for deceivers in the paired condition than deceivers in the individual condition. This difference due to co-presence was significant (U = 202, z = 2.422, p = .015), and represented a medium-sized effect (*r* = .42). Participants in the paired condition showed significantly more expressive facial cues (Mdn= 15561) than individuals (Mdn= 5988.5). Moreover, a Repeated Measures ANOVA was used to investigate the relative duration of five facial expressions (gaze aversion, blink, big smile, smile and pressed lips) regarding deception in co-presence. Results are described in table 1 regarding deception, co-presence whereas table 2 describes the mean amount and standard deviations of the five facial expressions exhibited by the children.

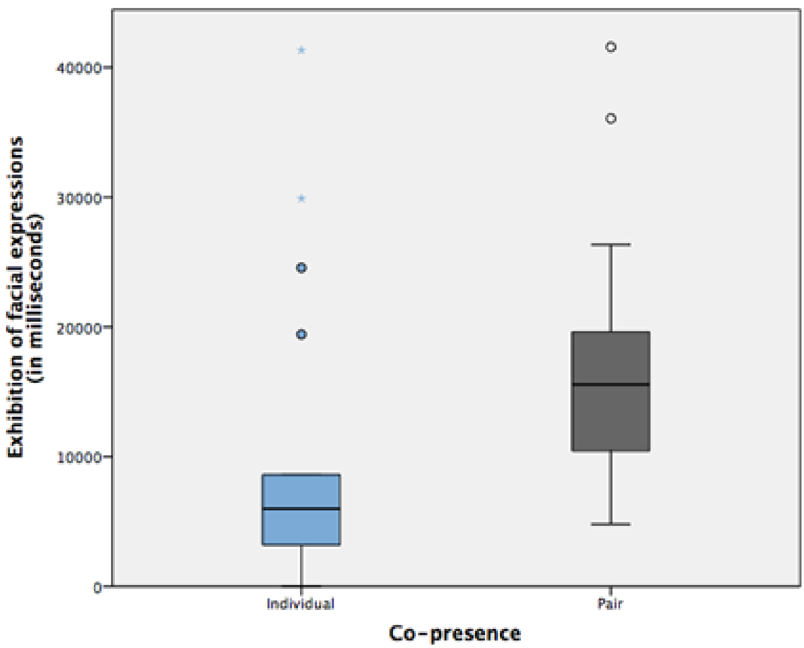

Figure 7: Overview of the facial expression exhibition in the individual and pair condition.

Table1: Results of the five facial expressions regarding deception in co-presence

Facial Expressions	**Deception**		**Co-presence**		**Deception*Co-presence**	
	F (1,31)	η^2	***F*** (1,31)	η^2	***F*** (1,31)	η^2
Gaze Aversion	14.496 **	.32	.025	.001	5.98*	.16
Blink	15.49 ***	.33	.286	.009	.911	.03
Big Smile	6.24*	.17	2.80	.083	4.91*	.14
Smile	20.29 ***	.39	2.82	.083	2.45	.07
Pressed Lips	17.24 ***	.36	7.02	.185*	3.02	.09

* $p< .05$ ** $p = .001$ *** $p< .001$

Table 2: Mean and Standard Deviations for each of the facial expressions

Facial Expression	Within-subjects factor	Between-subjects factor	*M*	*SE*
Avert Gaze	Deceptive	Individuals	1993.89	780.02
		Pairs	3251.17	854.47
		Total	2565.38	
	Truthful	Individuals	1361.94	383.62
		Pairs	351	420.23
		Total	902.42	
Blink (frequency)	Deceptive	Individuals	2	.44
		Pairs	2.5	.49
		Total	2.23	
	Truthful	Individuals	1.17	.22
		Pairs	1.13	.24
		Total	1.15	
Big Smile	Deceptive	Individuals	1176.39	925.98
		Pairs	4053.67	1014.36
		Total	2484.24	
	Truthful	Individuals	1001.94	473.95
		Pairs	1128.8	519.18
		Total	1059.61	
Smile	Deceptive	Individuals	1024.83	329.93
		Pairs	1868.27	361.42
		Total	1408.21	
	Truthful	Individuals	395.56	126.32
		Pairs	567.83	138.38
		Total	473.86	
Pressed Lips	Deceptive	Individuals	519.44	254.13
		Pairs	1394.83	278.39
		Total	917.35	
	Truthful	Individuals	94.44	74.83
		Pairs	357.5	81.97
		Total	214.02	

In particular, the results showed a significant main effect for deception on the durations of gaze aversion ($F(1, 31)= 14.496$, $p = .001$, $\eta^2 = .32$). Children averted their gaze significantly longer in the deceptive condition than in the truthful condition. In addition, there was a significant interaction effect between deception and co-presence for gaze aversion ($F(1, 31) = 5.98$, $p = .02$, $\eta^2 = .16$), in which pairs averted their gaze longer than individuals in the deceptive condition, but shorter than individuals in the truthful condition. Regarding blink, results showed a significant main effect of deceit for the number of times that children blinked ($F(1, 31) = 15.49$, $p < .001$, $\eta^2 = .33$). Children blinked significantly more in the deceptive condition than in the truthful condition. Regarding big smiles, there was a significant main effect of deception ($F(1, 31)= 6.24$, $p = .02$, $\eta^2 = .17$), and an interaction effect between deception and co-presence for the durations of big smiles ($F(1, 31)= 4.91$, $p = .03$, $\eta^2 = .14$). Children showed significantly more big smiles during the deceptive condition than in the truthful condition. Moreover, in the deceptive condition the average duration that children exhibited big smiles was significantly higher for children who participated in pairs than for children who participated individually. The results also showed a significant main effect of deceit for the exhibition of smiles ($F(1, 31)= 20.29$, $p <. 001$, $\eta^2 = .39$), as the smiles' duration is significant longer in the deceptive condition than in the truthful condition

A significant main effect of deceit for the exhibition of pressed lips was also found ($F(1, 31)= 17.24$, $p < .001$, $\eta^2 = .36$), and there was also a significant main effect of co-presence for pressed lips ($F(1, 31) = 7.015$, $p = .013$, $\eta^2 = .19$). Children pressed their lips significantly more in the deceptive condition than in the truthful condition. Moreover, in the paired condition they also pressed their lips significantly more than in the individual condition.

Finally, the results also showed large standard deviations in terms of positive nonverbal cues and facial expressions, which indicates not only some variability between children's nonverbal behavior, but also that level of expressiveness (i.e. the duration and the amount of facial expressions that one uses) is also child dependent.

Study 2

The second study extends the first study by a more explicit investigation of the facial movements that have been associated with deception, as an automated method that compliments the manually annotated data of Study 1. Facial movements can be described in terms of anatomically based action units, also abbreviated as AUs (Ekman & Friesen, 1976). These AUs are related to seven universal emotions, and have been associated with deception (DePaulo et al., 2003). Therefore, in this study facial action units (AUs) that are activated during deceit are examined using an automatic analysis tool.

Design

Study 2 used a 2x2 mixed design, with the independent variable deception (i.e. truthful or deceptive) as a within-subjects factor, and the independent variable co-presence (i.e. paired or individual) as a between-subjects factor. The intensity values of the AUs that children displayed served as the dependent variable(s) in Study 2.

Data analysis

The clips of truthful and deceptive utterances that were obtained with the elicitation game, that were separated and cropped, were also used for Study 2. The clips were analyzed with the use of the automatic analysis toolbox, Computer Expression Recognition Toolbox (CERT), to examine children's facial Action Units (AUs). In our analysis, we selected 4 AUs because these AUs had been associated with deceit in a previous meta-analysis (DePaulo et al., 2003). The 4 AUs selected were: (1) cheek raiser (AU6), (2) chin raiser (AU17), (3) lip tighter (AU23) and (4) lip presser (AU24). It should be noted that facial occlusion and aversive movement might have produced slight errors in the CERT output, even when in most of cases, the automated annotations were based on clean frontal recordings of children's faces. Occlusion of the face occurred when children covered their face with their hands, hair or glasses. In this case, CERT still tries to track facial muscle movements. In addition, CERT may not have recognized the face when children turned away their face during the experiment. Especially in the paired condition aversion movement was sometimes a problem, because CERT is then not able to recognize the face when the eyes and mouth are not clearly visible. Despite these disadvantages CERT produced different output weights for the facial AUs. Parts of the clips wherein the face was not recognized by CERT were not taken into account. The analysis provided output weights for each tracked facial AU in each frame. In order to make use of this raw data, the automated facial recognition approach from a previous study was used (Grafsgaard, Wiggins, Boyer, Wiebe, & Lester, 2013). Only the first two steps (i.e. individual adjustment and binary split) of this procedure were used, as explained below. The average value for each child was computed for all AUs in each condition (i.e. deceptive and truthful) separately. In this way, the values correspond to the individual baselines of the facial expressions. In the first step – Adjust CERT output - the output values produced by CERT were subtracted from the baseline of each individual in order to adjust the values to an average that was comparable across individuals. Subsequently, every positive value indicated that CERT recognized an AU. In the second step – Binary Split on Action Units (AU) - the values had to be reduced in order to reject false positives and negatives. Therefore, an empirically determined threshold of 0.25 was subtracted from the adjusted values. This value is based on instances in which CERT's output only slightly corresponds with the visible data. Note that there are only few studies that report on the analysis of facial expressions with this tool, specifically with children (Grafsgaard et al., 2013; Littlewort, Bartlett, Salamanca, & Reilly, 2011); due to the lack of comparable datasets and related research we decided to determine the threshold values on what has been proposed in previous studies available (Grafsgaard et al., 2013). For this analysis an automatic MATLAB script was used. The output of the validation process generated rich quantitative information for each participant, consisting of intensity and frequency values of AUs.

Results

Similar to study 1, the normality scores of the dependent variables were tested in the deceptive and truthful condition. Normality was tested per condition by assessing and evaluating the Kolmogorov-Smirnov test (the Kolmogorov-Smirnov test scores can be found in Appendix B, Table 3). The normality scores point to deviations from normality in the form of skewness and kurtosis, so that the *p*-values should be interpreted with some caution, but, again, deviations from normality are not viewed as major problems for ANOVA. Subsequently, a Repeated Measures ANOVA was used in order to examine the effect of deception and co-presence on the intensity values of the 4 AUs - cheek raiser (AU6), chin raiser (AU17), lip tighter (AU23) and lip presser (AU24) - during truthful and deceptive utterances for paired and individual children. Results showed a significant main effect of deceptiveness on chin raise (AU17), $F(1, 31) = 6.704$, $p = .015$). The intensity values of chin raise were higher in the deceptive condition ($M = .505$, $SE = .037$) compared to the truthful condition ($M = .396$, $SE = .035$), however there was no interaction effect between deceit and co-presence for chin raise, $F < 1$. Furthermore, there were no significant main or interaction effects for cheek raising (AU6), lip tightening (AU23) and lip pressing (AU24).

Study 3

The previous studies with manual coding and CERT-based analyses showed that children in deceptive contexts exhibit more facial cues than in truthful contexts, especially when there is another child co-present. Those findings beg the question as to whether such features could also serve as cues for observers to decide whether or not a child is telling the truth. To address this question, a perception test was carried out in order to examine observers' ability to distinguish between truthful and deceptive pairs and individuals. In the perception test, observers had to distinguish between lying and truthful pairs and individuals, based on the children's facial expressive behavior.

Design

Study 3 used a 2x2 between-subjects design. The independent variables were deception (i.e. truthful or deceptive) and co-presence (i.e. paired or individual), and the dependent variable was the percentage of correctly classified clips.

Participants

In the study 22 men and 38 women participated ($N = 60$), who were in the age of 18 to 80 years old ($M = 29.07$, $SD = 15.53$). The participants were recruited via friends, family and students from the social network of School of Humanities of Tilburg University.

Materials

The clips that were obtained with the elicitation game were also used for Study 3. However, the paired clips were adjusted so that the faces of the pairs were displayed together in a single frame. The reason for this was to understand the effects of co-presence in lying detection. In addition, the audio was removed from the clips to avoid a possible bias on the observers' judgments, since the goal was to rely on the children's facial expressions. The online survey tool Qualtrics was used to develop and run a survey. The survey contained 29 randomly selected clips of deceptive and truthful pairs and individuals, which featured 12 clips of pairs (7 deceptive and 5 truthful) and 17 clips of individuals (9 deceptive and 8 truthful). Only one of the conditions (i.e. the truthful or the deceptive clip) of the pairs and individuals was shown in the survey. The uneven distribution of deceptive and truthful clips was due to the fact that we had not received permission from all parents to show their children's clips in a perception test.

Procedure

Before the start of the main survey, participants were asked for their age and gender. In addition, to motivate the participants to be very precise and accurate in their responses, participants were informed that they could fill in their e-mail address at the end of the survey and win a book. Participants were also informed about the context of the game, i.e., that children were either being truthful or lying during the clips. The reason for this was related to the fact that we wanted to be as close to a real setting as possible, i.e., in most real-life situations people are aware about a possible lie when judging if someone is saying the true or not. Subsequently, the participants were shown 29 clips that contained deceptive or truthful interactions of pairs and individuals. Each clip lasted approximately 8 seconds and in total the survey lasted around 10 minutes. After watching each clip the participant had to fill in one question: I think these children are lying / I think this child is lying? With the answer possibilities: Yes or No. In the end of the survey participants could fill in their e-mail address and were thanked for their participation.

Results

In order to explore whether observers were able to accurately distinguish truthful and deceptive children above chance level based on the children's nonverbal facial expressions, the percentage of overall accurate answers was calculated for each participant separately (i.e. percentage of accurate answers for both paired and individual clips together). The accuracy percentage was calculated by dividing the number of correct answers by the highest possible score (i.e. 29), multiplied by 100. This resulted in a new variable that represented the percentage of correct answers, and it was normally distributed. Subsequently, the accuracy scores were compared against a 50% chance level score with the use of a One Sample T-Test. The results indicate that naïve observers were able to distinguish truthful and deceptive children above chance level, i.e., on average participants recognized 58.91% of the clips correctly (*SD*= 9.07%), and the difference of 8.91% was significant, $t(59)= 7.6$, $p < .001$, and represented a large-sized effect ($r^2 = .49$).

Study 1 already showed that pairs exhibit more facial cues to deception than individuals. In line with these results, observers may also be better able to distinguish between deceptive and truthful pairs than individuals. In order to test this assumption, the percentage of accurate answers was calculated for each participant for both conditions (i.e. paired clips and individual clips). A Paired Samples T-Test was used to examine any differences in accuracy scores due to co-presence of a peer. On average, participants recognized 66.94% (*SD*= 11.27) of the children in the paired condition correctly, compared to 53.24% (*SD*= 12.7) in the individual condition. This difference of 13.7% was significant, $t(59)= 6.5$, $p <.001$, and represented a large-sized effect ($r^2 = .42$). These results indicate that observers are better able to distinguish truthful and deceptive pairs than truthful and deceptive individuals, based on the children's nonverbal facial expressions.

Discussion

The present work has led to several interesting new insights with respect to deception, and in particular about deception towards virtual agents. First of all, to the best of our knowledge, this is the first study focusing on children's deceptive behavior in interactions with virtual agents. As these agents are designed and used to interact more and more with children (e.g. in games or learning tasks), it is important to understand how children view and experience such artificial conversation partners. Furthermore, to date only little was known about the nonverbal facial cues that children exhibit during deception in co-presence. In the past only, a few studies focused on the effect of co-presence on deception, even though lying is a social behavior that often occurs in the presence of more than one interactional partner. With the use of a newly developed child-friendly elicitation game, deceptive and truthful statements towards a virtual agent, in paired and individual children were elicited.

The lie elicitation game proved to represent a useful paradigm, since all children lied to the virtual agent in order to win the game, and save Princess Lily. This result goes in line with an earlier study (Serras Pereira et al., 2016) that showed that children can also easily lie to a robot dog and humanoid as they do in their human interactions. Moreover, in the present study children were consistent in their lies throughout the entire game. This points to the fact that children have a similar ToM when interacting with virtual agents as they do while interacting with humans, i.e., children also attribute mental states to virtual agents as they do human partners, even though admittedly we have not included comparison data in our current study in which child-agent interactions would be compared with human-human interactions. Moreover, more focused analyses in the future may be devoted to a deeper understanding of how e.g. ToM towards social agents is represented in children's minds. Yet, the outcomes are in line with findings from a previous study (Talwar, Gordon, et al., 2007) that showed that in order to successfully lie in human-human communication, children first need to understand their own mental state, and simultaneously the mental state of the communication partner to whom they are lying (first order belief), and at the same time they also need to keep semantic control over the lie tell (second order belief). Understanding children's ToM towards virtual agents is extremely relevant because these aspects should be taken into account when designing virtual agents for social settings that will serve different purposes in children's daily life, such as games that deal with problematic behaviors that involve lies, such as bullying.

Secondly, the outcomes of the first study regarding children's facial expressions show that children exhibited more positive facial expressions (i.e. smiles) during deceptive than truthful statements. This finding is in line with the results of several earlier studies that argue that deceptive children express more positive facial cues in order to cover their deceit (Talwar & Lee, 2002a; Talwar, Murphy, et al., 2007). Moreover, paired deceivers smiled more than individual deceivers. However, this difference caused by co-presence does not apply for truthful children. A possible explanation for this effect is that co-presence during deceit in a playful interaction with a virtual agent elicits excitation, and children become extra motivated in their attempt to hide their lie in co-presence of a peer, which goes in line with the excitation inhibition theory (Wagner & Lee, 1999). This would explain why co-presence only affected smiling in the deceptive condition and pairs did not smile more than individuals in the truthful condition. In addition, the results also showed that paired children generally exhibit more facial cues (i.e. are more expressive) than individuals. These results corroborate earlier studies that show an increase in children's nonverbal expressive behavior in co-presence (e.g. (Shahid et al., 2008). More generally, the analysis shows that several facial expressions are specifically associated with deceit. Gaze aversion, blinks, big smiles, smiles and pressed lips were exhibited significantly more by deceivers than by truth-tellers. These facial expressions are also distinguished by several prior studies (DePaulo et al., 2003; Talwar, Murphy, et al., 2007). Therefore, the results of the present study corroborate the outcomes of earlier research, and show that when children deceive a virtual agent, they exhibit similar facial cues as those found in human-human interaction. With regard to gaze aversion, it is possible that the increase of gaze aversions during deceit has to do with confirmation seeking. It seems that some children averted their gaze to rectify their lie and wondered if they were doing well (i.e., looked to the experimenter). Additionally, deceivers also avert their gaze more in co-presence of a peer. Earlier studies also indicate that children avert their gaze more while they lie (Talwar & Lee, 2002a). This result seems very relevant for the design of adaptable virtual agents. Having virtual agents that are able to interpret and adapt their behavior accordingly to children's gaze patterns can have an impact on how the communication evolves, for instance in cases where a social agent has to decide whether a child is being truthful or not. Moreover, children blinked more during their deceptive attempt than during their truthful utterance. With regard to this finding it should be noted that the majority of the children needed more time for their deceptive statement than for their truthful statement. Earlier research (Vredeveldt & Wagenaar, 2013) also indicated that it is easier to talk about an event that actually happened than an imagined event. The cognitive load that deception requires possibly explains the time difference, because children have to build up their lie. Hence, it is uncertain whether the increased number of blinks in the deceptive condition can be attributed to deception or possibly be explained by the average length of the deceptive statement. Although the results are not fully explained, blink rate can also be a relevant cue for virtual agents, particularly when designing adaptable agents for teaching and learning support, as learning also involves more cognitive load. Furthermore, in line with prior studies, deceivers press their lips more often than truth-tellers (Talwar, Murphy, et al., 2007). This result corroborates earlier studies which explain an unpleasant mouth expression as an attempt of the deceiver to avoid giving away cues to deceit (Talwar & Lee, 2002b). Perhaps children feel uncomfortable with telling a lie and the unpleasant mouth expression (i.e. pressed lips) is a leak of the child's actual emotional state during the deceptive utterance. Moreover, the exhibition of pressed lips is also found to be a sign of deception in adults (DePaulo et al., 2003). In sum, these results should be taken into account when designing adaptable agents, in particular those that can adapt and transform their behavior in real-time interaction, and make use of features like gaze aversion, pressed lips and smiles.

The second study extended the first study by further examining the facial action units (AUs) that are related to deceit, with the use of an automatic recognition tool. Results showed that the exhibition of chin raise (AU17) differs between deceivers and truth-tellers, i.e., deceptive children raised their chin significantly more than truth-tellers. This result is in line with the findings of prior studies (DePaulo et al., 2003). However, Study 2 showed no other significant differences for the facial AUs: cheek raiser (AU6), lip tighter (AU23) and lip presser (AU24). A possible explanation is that earlier studies that differentiated these AUs in relation to deceit were applied to adults (DePaulo et al., 2003). The AUs that are activated during deceit in children may differ from adults. Also, it could be that the manual coding of specific features, like pressed lips, deviates somewhat from the way such a feature is measured by means of CERT. However, other factors that may have influenced the analysis seem more likely, because the manual approach showed several significant differences that concern some of the AUs that are not significant in the automatic analysis. First of all, it is important to note that the deceptive and truthful conditions in the present study were relatively short for the automatic recognition tool CERT (Littlewort et al., 2011). Accordingly, the baseline condition to which the CERT output was adjusted might have been slightly biased. The AU's intensity values may become stronger when the deceptive and truthful conditions are measured during longer statements. Secondly, as explained before, facial occlusion might have produced slight errors, because several children covered their face with their hands, hair or glasses during the deceptive or truthful statement. Thirdly, while CERT managed to produce automatic outputs in the majority of the cases, lateral movement of the children have affected the data, because in this case CERT was not able to recognize the face. This happened predominantly in the paired condition, which resulted in a poor comparison between paired and individual children. In future research, it is wise to use technology that not only allows measuring facial expressions, but it also takes into account in-depth movement of the children.

Additionally, it appears that children who are in co-presence of a peer leak more cues to their deceit than individual deceivers. Consequently, the present study was also interested in observers' ability to recognize deception in paired and individual children. For the third study, a perception test was carried out to examine observers' ability to recognize deceptive and truthful children. The outcomes of the first analysis showed more positive detection results than we typically observe in previous judgments studies, because observers were able to accurately distinguish between truthful and deceptive children (i.e. individuals and pairs) above chance level, whereas several previous studies prove that observers scored slightly below or only at chance level (e.g Swerts et al., 2013; Strömwall & Granhag, 2007). Possible explanations are that in the present study, observers were intentionally informed about the context of the children's deceptive behavior. This means that the observers were informed about the situation and circumstances (i.e. context) in which the children lied or told the truth. Several earlier studies did not inform observers about the context of the lie, which does not represent a situation in everyday life very well and may have made correct recognition more difficult. The study showed that observers were better able to distinguish between truthful and deceptive pairs than truthful and deceptive individuals. This result is consistent with the findings of Study 1 that indicate that on average paired children leak more cues to deceit than individuals. Perhaps observers are better able to distinguish deceivers in co-presence, because they exhibit more facial expressions and leak more cues to their deceit. For future research it might also be interesting to retest observers' accuracy scores when observers (humans and social agents) are informed about the cues to deception (that are demonstrated in the present study) prior to the perception test.

To sum up, the results of our study are very interesting, not only because they have shown how children experience virtual agents, but also because they generated new insights that are relevant for the design of future virtual agents. We have highlighted throughout the entire discussion the possibilities of using children's facial expressions (e.g. gaze patterns, blink rate) as input for the design of virtual agents, i.e., using these cues to build up better and smarter virtual agents that are able to read these cues and adapt their behavior in real time. A very specific application regards the use of virtual agents for juridical and educational contexts, where it is important to note that children in our study perceived these agents as real partners, and therefore could build rapport and the necessary trust that such contexts need.

For example, having such kind of agents in court situations, where children must testify, can be valuable for checking the veracity of the testimonials based on children's nonverbal behavior. Maybe they can also be used for diagnosis of atypical populations (like for children with autism), as these children have been argued to have an impoverished ToM, especially in interactions with real human beings, but appear to have problems building rapport with artificial partners. Finally, another advantage is that these virtual agents can be programmed such that they behave the same to any child, which also brings an experimental advantage compared to having human partners.

Conclusion

To conclude, the present work illustrated a compelling new way to examine children's facial expressions that were exhibited during truthful and deceptive interactions with a virtual agent. An interactive lie elicitation game was developed to record children's facial expressions during deceptive and truthful utterances, in an individual or co-presence situation. This study provides new and interesting insights regarding children's lying behavior towards virtual agents. More specifically, it adds to our understanding of how children interact while lying to these entities, and sheds some light on how these agents might be represented in terms of children's ToM. That opens interesting possibilities for the use of such agents in therapy and developmental research: on the one hand, these agents have the advantage that they can programmed in a consistent and systematic manner, while, on the other hand, they still seem to be viewed as "real" conversation partners by the children, so that their resulting behavior has ecological validity. Finally, the first two studies prove that children leak cues to deception, as their deceit can be traced from their facial expressions. Results show that the facial expressive behavior of deceivers and truth-tellers differs significantly, and co-presence affects children's deceptive behavior. It appears that children who are in co-presence of a peer leak more cues to their deceit than individual deceivers, in particular regarding exhibition of smiling and gaze aversion. Consequently, the present study was also interested in naïve observers' ability to recognize deception among paired and individual children. In future studies it would seem useful to explore the cue validity of these nonverbal cues, not only for (automatic) lie detection (for which a larger database of recorded children would seem necessary), but also for the design of adaptable virtual agents that support children's daily tasks, such as persuasive games for behavior change.

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Appendix A

Manual coding scheme

Table 1. Nonverbal facial expressions coding scheme

Sections	Actions
Eyebrows	Brow heightened
	Brow lowered
Eyes	Avert gaze
	Blink
	Lid tighten
	Eyes widen
Nose	Wrinkle nose
Mouth	Big smile
	Slight smile
	Pouting lips
	Pressed lips
	Show tongue
Chin	Chin raise
Head	Turn head left or right
	Lift head
	Lower head

Appendix B

Normality test statistics (Study 1)

Table 1.Normality scores of positive facial expressions for individuals and pairs

Condition		Skewness	Kurtosis	K-S test (sig)
Deceptive	Individuals	1.32	- 0.99	*D*(18) = .137, *p* = .200
	Pairs	0.26	0.19	*D*(15) = .201, *p* = .105
Truthful	Individuals	0.16	0.08	*D*(18) = .320, ***p* < .001**
	Pairs	- 5.04	- 1.08	*D*(15) = .116, *p* = .200

Note. Significant deviations from normality are indicated in bold

Table 2. Normality scores of the total amount of facial expressions for individuals and pairs

Condition	Skewness	Kurtosis	K-S test (sig)
Individuals	0.3	0.39	*D*(18) = .332, ***p* <.001**
Pairs	0.53	1.18	*D*(15) = .208, *p* = .079

Note. Significant deviations from normality are indicated in bold

Normality test statistics (Study 2)

Table 3. Kolmogorov-Smirnov test scores of four facial action units (AUs) for individuals and pairs

Facial expression	Condition	Skewness		Kurtosis		Kolmogorov-Smirnov test (sig)	
		Individual	Pairs	Individual	Pairs	Individuals (*N*= 18)	Pairs (*N*= 15)
AU6 (Cheek Raise)	Deceptive	2.0	.66	5.3	-.61	*D*(18) = .220, *p* = **.021**	*D*(15) = .166, *p* = .2
	Truthful	1.4	-.39	1.0	-.38	*D*(18) = .198, *p* = .059	*D*(15) = .259, *p* = **.008**
AU17 (Chin Raise	Deceptive	-.41	-.26	-1.4	-.99	*D*(18) = .253, *p* = **.003**	*D*(15) = .101, *p* = .2
	Truthful	.19	.05	-1.6	-1.0	*D*(18) = .288, *p* **< .001**	*D*(15) = .160, *p* = .2
AU23 (Lip Tighter)	Deceptive	-.23	.08	-1.1	-.82	*D*(18) = .192, *p* = .079	*D*(15) = .123, *p* =.2
	Truthful	.15	1.5	-.64	3.4	*D*(18) = .220, *p* = **.022**	*D*(15) = .185, *p* = .180
AU24 (Lip Presser)	Deceptive	1.3		.71		*D*(15) = .407, *p* **< .001**	
	Truthful	1.1		-.33		*D*(15) = .411, *p* **< .001**	

Note. Significant deviations from normality are indicated in bold.

6

General Discussion & Conclusion

General Discussion

This dissertation aimed to examine children's deceptive behavior. Specifically, the goal was to identify possible verbal and nonverbal correlates of deception, explore the effect of different types of social partners and of context on children's deceptive behavior, and investigate the extent to which deception can be detected by humans and by computers. To this end, we used a multimodal approach, in which 4 independent experimental studies were conducted. All studies were based on analyses of children's lies that were elicited in (semi) spontaneous settings, i.e., settings that resemble real life situations, but of which certain aspects were controlled. In the analyses, we focused both on verbal and/or nonverbal cues that children exhibited during a lie while interacting with different kinds of communication partners (humans vs. artificial partners) and in different social context (alone or in co-presence); those studies were complemented with perception experiments in which we explored whether judges could separate deceptive from truthful behavior.

In the core chapters of this dissertation, the four experimental studies are described in detail, and will be briefly summarized here. The first study (chapter 2) explored the cue validity of body movement and nonverbal cues for lie detection. To achieve this, we introduced an innovative methodology – the combination of perception studies (using eye-tracking technology) and automated movement analysis. More specifically, we conducted an automatic analysis of children's body movement during truthful and deceptive interactions. We also conducted two perception studies to understand whether human judges could distinguish lies based solely on children's nonverbal behavior, and to check whether certain bodily regions of the child provided more informative cues about deception. The next chapter (chapter 3) investigated acoustic properties of children's speech in deceptive and truthful interactions. In this study, a combination of manual and automatic methods was used to analyze long and small speech utterances of children in deceptive and truthful interactions. Whereas these first 2 chapters mainly focused on verbal and nonverbal cues of children's deceptive behavior in interaction with human partners, the next chapters (chapter 4 and 5) focused on children's deceptive behavior in interactions with artificial partners. The study in chapter 4 compared children's lying behavior in interactions with different communication partners, specifically with robots versus a human partner. Children's verbal behaviour and facial expressions were analysed by means of automated methods. Finally, chapter 5 looked at the facial expressions that children exhibit while trying to deceive a virtual agent. Moreover, the impact of social context (alone or in-co-presence of a peer) was also explored to investigate possible effects of co-presence on lying behavior. Here again, a combination of a manual method together with an automatic recognition approach was used to examine facial expressions of children, who had been interacting with a virtual agent, either alone or together with another child. And we also conducted a perception study to find out whether recordings of children in a co-presence condition can enhance accurate lie detection.

In the current chapter, we reflect on the main findings of the previous chapters, and elaborate on the implications and possible future directions for research, albeit that more specific issues have already been discussed in the previous chapters themselves.

Children's deceptive behavior

The present dissertation has explored to what extent differences in the type of interaction may affect a child's deceptive behavior. In this section, we zoom in on the possible impact of the type of dialogue partner and of co-presence (i.e., whether children are alone or together with another child).

First of all, this dissertation explored children's deceptive behavior towards human (chapters 2, 3 and 4) and artificial partners, in particular robots (chapter 4) and virtual agents (chapter 5). A first general observation is that children lied to all of these addressees, but that there were also differences dependent on whom they were addressing. On the one hand, we observed that children lied more to the robots then to human partner, suggesting that children consider these two partners to be different. Because lying has a moral (negative) valence attached to it (Talwar & Lee, 2002a), children might have considered that lying to robots was less harmful than lying to humans. On the other hand, however, there are different results that seem to point out that interaction with humans or artificial partners are quite similar in other respects. First, children between 4-6 years old, irrespective of whether they are lying to robots or to human partner, showed semantic leakage during the deceptive interaction. Semantic leakage has been argued to be due to the difficulty children experience to keep the information of the initial lie consistent with follow-up statements. These results are consistent with those of previous studies (Talwar, Gordon, & Kang, 2007; Talwar & Lee, 2002a), and reinforce the idea that children find lying to artificial partners as hard as to human partners. The latter type of findings suggest that the way children attribute mental states to robots or virtual agents is not essentially different from how they do this with human partners, and that their ToM proceeds similarly in interactions with both artificial and human addressees. That finding is particularly relevant in view of the fact that socially intelligent agents are becoming increasingly more important in of children's daily lives, and become particularly relevant for designing artificial agents that serve roles in games that deal with problematic behaviors that involve lies, such as bullying.

Secondly, as mentioned before, an important gap in previous research concerns the fact that many studies have ignored social factors that may influence children's deceptive behavior. That is surprising given that the act of lying is often a social behavior that tends to occur in the presence of other social partners. In children's behavior, this seems even more relevant, especially as often children lie together in order to avoid punishment, and in that sense, are co-responsible for the deceptive act. It is surprising that there are only a few studies that explore children's deceptive behavior in the presence of other people, apart from a few that focus on the cue validity of co-presence for lie detection (Strömwall & Granhag, 2007; Swerts, 2012).

One of the contributions this dissertation brings was to further understand the role that co-presence can have on children's deceptive behavior. The study in chapter 5 showed that co-presence affects children's deceptive behavior, as children who are in co-presence of a peer leak more nonverbal cues during their deceptive interactions than individual deceivers. This was most clearly the case for the amount of smiling and gaze aversion. In the next section we will reflect further on the implications of this for lie detection.

Deceptive cues and Lie detection

All the studies in the chapters of this dissertation have explored the actual cues to deception that children displayed in their interactions. To this end, we used a multimodal approach that consisted of a mix of manual and automated techniques to analyze either verbal and/or nonverbal behavior as potential cues to deception, combined with perception studies for the study of lie detection. This combination of methods proved to be a useful, as findings of one technique were corroborated by that of another one. For instance, in chapter 5, most of the children facial expressions that were associated to deceptive behavior by means of a manual coding scheme were also recognized as deceptive cues with an automated facial analysis. In chapter 2, that introduced an automated way of analyzing children's body movement showed that children tend to exhibit more body movement during deceptive interactions, which correlated positively with the accuracy level of lie detection by human judges.

Throughout the 4 studies, we have shown clear evidence that children show different kinds of bodily cues during deceptive interactions. In chapter 2, as already mentioned, an automated movement analysis showed evidence that children tend to move more during deceptive interactions. Chapter 4 used an automatic facial expressions approach to analyze children's facial expressions during deceptive interactions with robots. Particularly, it was found that children showed more joy when interacting with robots. The analyses of chapter 5 revealed that several facial expressions are specifically associated with deceit. Gaze aversion, blinks, big smiles, smiles and pressed lips were exhibited significantly more by deceivers than by truth-tellers, in line with the outcome of several prior studies (DePaulo et al., 2003; Mann et al., 2013, 2002, 2004). Moreover, chapter 5 also explored the effect of co-presence on children's deceptive behavior, and found that paired deceivers not only exhibited more facial cues (i.e. are more expressive) than individuals, but also smiled more than individual deceivers. These results corroborate earlier studies that show an increase in children's nonverbal expressive behavior in co-presence (e.g. Shahid et al., 2008), and also shed a new light on the impact that co-presence can have on children's deceptive behavior.

Apart from the bodily cues, Chapter 3 also examined the acoustic properties of children's speech during deceptive and truthful interactions. To the best of our knowledge, previous studies have only focused on adults' deceptive speech (Benus et al., 2006; Ekman, O'Sullivan, Friesen, & Scherer, 1991; Hirschberg et al., 2005). Results revealed that Long Pauses (LP) and Filled Pauses (FP) are less frequent in children's deceptive interactions compared to the truthful ones, while Prolonged Words (PLW) occurred more often in deceptive speech. Moreover, an acoustic analysis showed that children's deceptive speech had higher levels of intensity but also less jitter variation when compared to truthful utterances. Additionally, chapter 4 also showed that children's pitch during deceptive interactions with robots also shows more variations, supporting a previous finding that pitch can change with deceptive behavior (Streeter, Krauss, Geller, Olson, & Apple, 1977).

Given that we found that deceptive utterances are accompanied with specific verbal and nonverbal features, we were interested in whether these could have functioned as cues for lie detection. Previous studies on lie detection have shown that lie detection accuracy with human judges is usually not much better than chance level, if significant at all (Bond & Depaulo, 2006; Edelstein et al., 2006; Swerts et al., 2013). Quite in contrast with those earlier findings, our own study revealed that several verbal and nonverbal cues were much more potentially useful as cues to children's deceptive behavior, based both on automated analysis and manual coding schemes. The interesting features appeared to be: (big) smiles, gaze aversion, eye blinks, pressed lips, general body movement, prolonged words and higher levels of intensity in speech. Moreover, deceptive speech revealed to have less jitter variation, and less long pauses and filled pauses. This set of verbal and nonverbal cues particularly when combined could improve lie detection accuracy.

Secondly, in 2 studies of this dissertation perception studies with human judges where conducted to investigate the nonverbal cues validity for lie detection. Specifically, human judges were asked to guess whether a child was being truthful or lying based on their nonverbal behavior. The study presented in chapter 2, consisted of stimuli in which full body of the children were presented to participants, while in chapter 5 only the face of the children was shown. Results of the latter study revealed that participants were able to distinguish truthful clips from lying clips above chance level solely based on children's facial cues. This is consistent with reports of the judges of the first perception study that they based their decision primarily on features in the children's faces. In line with this, the eye-tracking study of that first study revealed that, even when there was movement happening in different body regions, as illustrated by the automated movement analysis, it appeared that judges tended to limit their main focus of attention to the face region. Chapter 5 focused on lie detection based only on children's facial expressions in co-presence. Results showed that not only lie detection accuracy was above chance level, but also that judges were better able to distinguish truthful and deceptive pairs than truthful and deceptive individuals, based on the children's nonverbal facial expressions. These findings are in line with previous studies that showed evidence that co-presence can empower lie detection (Strömwall & Granhag, 2007; Swerts, 2012).

Implications & Future directions

The result of our dissertation has generated a number of significant implications for the study of children's deceptive behavior.

First, we would like to stress the importance of using a multimodal approach to study deceptive behavior. The inconsistencies reported in the past might not only be explained by the idiosyncrasy of lies, but also because there is such variability in the methods used to investigate it. Combining manual and automated methods to analyze deceptive behavior has proven to be a very efficient and reliable approach to identify verbal and nonverbal cues to children's deceptive behavior. Moreover, perception studies allowed to assess lie detection, where it was specifically interesting that it highlighted the impact of co-presence for lie detection. Moreover, the use of eye tracking technology in one of these studies, allowed us to learn more about the regions of the body that influenced the judges' decision regarding lie detection, which nicely supplemented the judges' self-reports. In future studies, it would seem useful to explore the cue validity of all the cues (identified in these manuscript), not only for automatic lie detection, for which a larger database of recorded children seems necessary, but also for the training of experts who would be helped by accurate measures of lie detection, such as in legal settings.

The second contribution concerns the lie elicitation paradigms we used in all four studies. These production studies that were game-based were inspired by previous studies (Swerts, 2012; Talwar & Crossman, 2011; Talwar & Lee, 2002a, 2002b), and turned out to be particularly useful, especially in view of the fact that we were dealing with child participants. This approach allowed us to elicit lies in spontaneous, yet controlled settings that resembled natural contexts of children's daily life, i.e., school is a very natural setting for children, where most of them feel comfortable and secure, and games are also normal activities of daily life. In this sense, these lie elicitation paradigms were designed to be very close to daily life settings, where usually children's lies occur. The paradigm also allowed exploring the effect of co-presence on children's deceptive behavior, which is important in view of the fact that children dynamically interact with peers during games in general, and in deceptive contexts in particular.

Finally, by exploring the role of different communication partners (artificial vs. human) on children's' deceptive behavior, we have learned more about how children perceived these types of partners, and in particular about how it affected their ToM. The findings in this dissertation suggested that children's ToM regarding artificial partners (robots and virtual agents) is very comparable to children's ToM towards human partners, i.e., it seems that children attribute similar mental states to the artificial partners as they do with people. This has some promising implications for the use of such agents in therapy and developmental research: on the one hand, these agents have the advantage that they can be programmed in a consistent and systematic manner, while, on the other hand, they still seem to be viewed as "real" conversation partners by the children, so that their resulting behavior has ecological validity.

Conclusion

The present dissertation has generated a number of interesting findings regarding children's deceptive behavior. We have learned more about verbal and nonverbal cues to children's lies, and we explored the influence of different social partners and the effect of co-presence on deceptive behavior. In addition, we have tried out a number of automated and manual procedures to detect features to deception, and conducted perception experiments to check to what extent judges were able to distinguish truthful from deceptive utterances. We have shown that it is useful to study different aspects of children's deceptive behavior via a combination of manual, automated and perceptive methods.

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Summary

This dissertation aimed to examine children's deceptive behavior. In particular, the goal was to identify possible verbal and nonverbal correlates of deception, explore the effect of different types of social partners and of context on children's deceptive behavior, and investigate the extent to which deception can be detected by humans and by computers. To this end, we used a multimodal approach that led to 4 independent experimental studies. All studies were based on analyses of children's lies that were elicited in (semi-)spontaneous settings, i.e., settings that resemble real life situations, but of which certain aspects were controlled. In the analyses, we focused both on verbal and/or nonverbal cues that children exhibited during a lie while interacting with different kinds of communication partners (humans vs. artificial partners) and in different social context (alone or in co-presence); those studies were complemented with perception experiments in which we explored whether judges could separate deceptive from truthful behavior.

The first study (chapter 2) investigated how easily it can be detected whether a child is being truthful or not in a game situation, and it explored the cue validity of bodily movements for such type of classification. To achieve this, we introduced an innovative methodology – the combination of perception studies (in which one used eye-tracking technology) and automated movement analysis. Film fragments from truthful and deceptive children were shown to human judges who were given the task to decide whether the recorded child was being truthful or not. Results revealed that judges were able to accurately distinguish truthful clips from lying clips in both perception studies. Even though the automated movement analysis for overall and specific body regions did not yield significant results between the experimental conditions, we did find a positive correlation between the amount of movement in a child and the perception of lies, i.e., the more movement the children exhibited during a clip, the higher the chance that the clip was perceived as a lie. The eye-tracking study revealed that, even when there is movement happening on different body regions, judges tend to focus their attention mainly on the face region.

The second study (chapter 3) explored acoustic properties of children's speech in deceptive and truthful interactions. The analyses were based on recordings obtained through a lie elicitation game in which children were either being truthful or lying about an object hidden behind their back. The game was played in a truthful condition and in two lying conditions (Ly1 and Ly2). Results revealed that Long Pauses (LP) and Filled Pauses (FP) are less frequent in the deceptive interactions compared to the truthful ones. Moreover, Prolonged Words (PLW) occurred more often in deceptive speech than in truthful speech. Lastly, an acoustic analysis showed that children's deceptive speech had higher levels of intensity but also less jitter variation when compared to truthful utterances.

The third study (chapter 4) examined how young children between 4 - 6 years old interact with personified robots during a lying situation. To achieve this, a temptation resistance paradigm was used, in which children were instructed to not look at a toy (behind their back) while the instructor (a robot dog, a humanoid or a human) left the room. Results revealed that regardless of the type of communication partner, children's peeking behavior was similar across the 3 conditions, while there was a tendency of lying more towards the robots. Most of the children (98%) showed semantic leakage while telling a lie, and most of them (89%) lied and denied their peeking behavior. Additionally, children generally gave more verbal responses to the robot dog and to the humanoid in comparison with the interaction with the human. Furthermore, the mean pitch of children differed between the robot conditions, i.e. the mean pitch was significantly lower in the robot dog condition in comparison with the humanoid condition. Finally, facial expression analysis showed that children generally appeared happier when they were interacting to the robot dog compared to the humanoid or human.

Finally, the fourth study focused on the facial expressions that children exhibit while trying to deceive a virtual agent. An interactive lie elicitation game was developed to record children's facial expressions during deceptive and truthful utterances. Our participants did this task either alone or in the presence of peers. A manual method and an automatic recognition approach were used to examine facial expressions and facial action units (AUs). Results show that the facial expressions of deceivers differ from those of truth-tellers: most clearly, they try to cover their lie as they smile significantly more often than truthful children. Moreover, co-presence enhances children's facial expressive behavior and the number of deceptive cues. Furthermore, a perception test with children's video-clips that had been selected from the individual or paired sessions show that observers are able to distinguish young deceivers from truth-tellers above chance level. Moreover, observers found it easier to discriminate between deceivers and truth-tellers who had played the game in the co-present condition. Our research thus shows that virtual agents can be used as tools to elicit lies in a playful manner, which would be relevant for developmental, educational and behavioral analyses of deceit in growing children.

Overall, this dissertation contributes to further understand children's deceptive behavior. We have shown clear evidence that children show different kinds of bodily cues during deceptive interactions. Study 1 revealed children tend to move more during deceptive interactions. More specific analyses of study 3 showed that children exhibited more joy when interacting with robots, while study 4 revealed that several facial expressions are specifically associated with deceit (gaze aversion, blinks, big smiles, smiles and pressed lips). Moreover, this study also explored the effect of co-presence on children's deceptive behavior, and found that paired deceivers not only exhibited more facial cues (i.e. are more expressive) than individuals, but also smiled more than individual deceivers. These results corroborate earlier studies that show an increase in children's nonverbal expressive behavior in co-presence.

Furthermore, we observed that children lied more to the robots then to human partner, suggesting that children consider these two partners to be different. Because lying has a moral (negative) valence attached to it, children might have considered that lying to robots was less harmful than lying to humans. On the other hand, however, there are different results that seem to point out that interaction with humans or artificial partners are quite similar in other respects. First, children between 4-6 years old, irrespective of whether they are lying to robots or to human partner, showed that children experience problems to keep the information of the initial lie consistent with follow-up statements. The latter type of findings suggest that the way children attribute mental states to robots or virtual agents is not essentially different from how they do this with human partners. That finding is particularly relevant since socially intelligent agents are becoming increasingly more important in of children's daily lives, and become particularly relevant for designing artificial agents that serve roles in games that deal with problematic behaviors that involve lies, such as bullying.

Thirdly, previous studies on lie detection have shown that lie detection accuracy with human judges is usually not much better than chance level, if significant at all. Quite in contrast with those earlier findings, our own study revealed that several verbal and nonverbal cues were much more potentially useful as cues to children’s deceptive behavior, based both on automated analysis and manual coding schemes. The interesting features appeared to be: (big) smiles, gaze aversion, eye blinks, pressed lips, general body movement, prolonged words and higher levels of intensity in speech. Moreover, deceptive speech revealed to have less jitter variation, and less long pauses and filled pauses. This set of verbal and nonverbal cues particularly when combined could improve lie detection accuracy.

Finally, the result of our dissertation has generated several significant implications for the study of children’s deceptive behavior. We would like to stress the importance of using a multimodal approach to study deceptive behavior. The inconsistencies reported in the past might not only be explained by the idiosyncrasy of lies, but also because there is such variability in the methods used to investigate it. Combining manual and automated methods to analyze deceptive behavior has proven to be a very efficient and reliable approach to identify verbal and nonverbal cues to children’s deceptive behavior. Moreover, perception studies allowed to assess lie detection, where it was specifically interesting that it highlighted the impact of co-presence for lie detection. Additionally, the use of eye tracking technology in one of these studies, allowed us to learn more about the regions of the body that influenced the judges’ decision regarding lie detection, which nicely supplemented the judges’ self-reports. In future studies, it would seem useful to explore the cue validity of all the cues (identified in these manuscript), not only for automatic lie detection, for which a larger database of recorded children seems necessary, but also for the training of experts who would be helped by accurate measures of lie detection, such as in legal settings.

Acknowledgments

How many times have I thought about writing this last bit? Because this would mean that the journey was ending, and I was about to cross the finish line! Four and half years have passed, and it seems like a life time! I remember that when considering moving to the Netherlands, my husband (at the time my boyfriend) was always talking about the amount of opportunities and things I could do as a (clinical) psychologist… and I would listen, smile, be nervous, and doubt about it. But this kept me dreaming, and fighting for what I wanted. I knew when I moved almost 10 years ago that I wanted to do a Ph.D. It wasn't a straight forward road, until I got the opportunity. But here I am today!

The first time I met Marc and Suleman, my supervisors, I was doing a PDEng at TuE, and they were teaching there. At that time, I approached Marc about Ph.D. opportunities, and he told me while rushing to the university *"sometimes opportunities show up in Tilburg, keep an eye, and if you see something that interests you, let me know!"*. Meanwhile, I would 'occasionally' mention to Suleman my wish of pursuing a Ph.D. And then, one day I got an email from him about an open application for Ph.D. proposals at Tilburg University. And that was my shot! And guess what?! Two rounds of interviews (while 38 weeks pregnant and praying not to go into labor), another written assignment, a baby born meanwhile, and one last interview via skype while doing Kangaroo care to my baby (hoping she wouldn't start yelling)… and I didn't get the position! I was 3rd, and there were only 2 positions available! I got a very nice email about my qualities, but I didn't' get the position. Fast forwarding some weeks, I got an email from Marc asking, "still interested in a Ph.D.?". And that was it! I even got a much cooler topic than my initial proposal. Children's Deceptive behavior. Really?! Who spends 4 years of her life putting kids in situations where they must lie? And then, study their behavior? How cool!

So, here I am crossing the finishing line. The first person I want to thank is my supervisor Marc Swerts. It was a pleasure, a wonderful journey, and for sure I couldn't have done it without your full support. And, I'm very grateful for that. You taught me so much, but above all what I take with me is your perspective of always looking at the brighter side of life, or in this case, of my Ph.D. journey. When I struggled, you always showed me what I had achieved so far. From your eyes, the glass seemed always half full, and not half empty as I often thought! And that made me go through! And then, your magical touch of putting ideas, experiments and pieces of text in a full coherent and nice story! I also admire your creativity, always thinking about cool and funny experiments! So, thank you very much!

To Suleman, my co-supervisor, if you hadn't send that email about that Ph.D. position, I probably wouldn't be here today. Your creativity, persistence, and ambition to design nice and fun experiments were a lesson to me. I'm very grateful for your support. Thank you!

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To my team at StudyPortals - PIT - you have met me in one of the most challenging and busy periods of my life! Going from a full time Ph.D. position to a full-time product researcher position in an awesome company, while using the evenings to finish my dissertation, was quite an adventure. Thank you for listening to me, for the encouragement when I doubted it, and for making me smile and laugh when I thought I couldn't manage it. A special thanks to Toon van Craenendonck for giving me the chance to work at StudyPortals, while giving me also the freedom and full support to finish my Ph.D.!

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There are other people that I'm eternally thankful to, and those are my parents, family and Portuguese friends. I will switch to Portuguese now (back to English in the end), I'm sorry for the inconvenience… but there is always Google translate!

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Publication list

Journal Publications

Serras Pereira, M., de Lange, J., Shahid S. and Swerts, S. (2017). A perceptual and behavioral analysis of facial cues to deception in interactions between children and a virtual agent. International Journal of Child-Computer Interaction (accepted for publication)

Serras Pereira, M., Cozijn, R., Postma, E., Shahid, S., & Swerts, M. (2016). Comparing a Perceptual and an Automated Vision-Based Method for Lie Detection in Younger Children. Frontiers in Psychology, 7, 1–12. http://doi.org/10.3389/fpsyg.2016.01936

Book Chapter

Serras Pereira, M., Shahid, S. and Swerts, S. Acoustic properties of children's speech in truthful and deceptive interactions. Palgrave Handbook of Deceptive Communication (accepted for publication).

Papers in conference Proceedings (peer reviewed)

Serras Pereira, M., de Lange, J., Shahid,S. and Swerts,M. (2016). Children's Facial Expressions in Truthful and Deceptive Interactions with a Virtual Agent. In Proceedings of the 4th International Conference on Human Agent Interaction (HAI '16). 289-296.

Serras Pereira, M., Nijs, Y., Shahid, S., & Swerts, M. (2016). Children's lying behavior in interactions with personified robots. In Proceedings of the 30th International BCS Human Computer Interaction Conference*: Fusion! (*HCI'16). (oral presentation).

Serras Pereira, M., Postma, E., Shahid, S. & Swerts, M. S. (2014). Are You Lying to Me? Exploring Children's Nonverbal Cues to Deception. In Proceedings of 36th Annual Conference of the Cognitive Science Society ,2901–2906.

Abstract of Conference presentations (peer reviewed)

Serras Pereira, M., Shaihd, S., Postma, E.& Swerts, M. (2015). Is your body lying? Exploring bodily cues for deception using an automated movement analysis. In Proceedings of The 1st Joint Conference on Facial Analysis, Animation and Auditory-Visual Speech Processing (oral presentation)

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“A LIE KEEPS GROWING AND GROWING UNTIL IT’S AS PLAIN AS THE NOSE ON YOUR FACE.”

- BLUE FAIRY